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# ANNUAL REPORT

OF THE

# NATIONAL BOARD OF HEALTH.

1881.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1882.

B1
1881

# LETTER

FROM

# THE SECRETARY OF THE TREASURY,

TRANSMITTING

*The Report of the National Board of Health for the fiscal year ending June 30, 1881.*

---

JANUARY 11, 1882.—Referred to the Committee on Public Health, and ordered to be printed.

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TREASURY DEPARTMENT,
*December* 6, 1881.

SIR: In compliance with the requirements of section 4 of the act of June 2, 1879, I have the honor to transmit herewith the annual report of operations and expenditures of the National Board of Health for the fiscal year ending June 30, 1881.

Very respectfully,

CHAS. J. FOLGER,
*Secretary.*

Hon. J. WARREN KEIFER,
*Speaker House of Representatives.*

## *THE NATIONAL BOARD OF HEALTH.*

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# ANNUAL REPORT

OF THE

# NATIONAL BOARD OF HEALTH,

WITH STATEMENT OF EXPENDITURES, FOR THE FISCAL YEAR ENDING JUNE 30, 1881.

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NATIONAL BOARD OF HEALTH,
*Washington, D. C., November* 14, 1881.

Hon. HENRY F. FRENCH,
*Acting Secretary of the Treasury:*

SIR: In compliance with the provisions of section 4 of the act approved June 2, 1879, entitled "An act to prevent the introduction of contagious and infectious diseases into the United States," the National Board of Health respectfully submits its third annual report.

Hitherto, for reasons which the board considered to be of some importance with reference to the convenience of administrative operations during the period at which infectious fevers were likely to exist, the annual report has not been drawn up until the close of the calendar year. This having been made the subject of disapproving criticism, so far at least as refers to the transmission of the estimates for the next fiscal year, the board, in deference to the supposed intention of Congress, proposes to conform to the common usage of the various bureaus of the government in regard to the commencement and end of the administrative year.

## ANNUAL REPORT, 1881.

### SPECIAL SCIENTIFIC INVESTIGATIONS.

In the last annual report, dated January 1, 1881, it was considered proper to refer in a general way to all the scientific investigations which had been set on foot by this board since its organization, and they were accordingly enumerated *seriatim*.

Of the entire number then stated to be in progress, some have been since completed and others so far advanced as either to have admitted of being partially reported in preliminary papers, or only to require a brief delay for completing the record of the experiments and observations. The following (I to IV inclusive) are in the former class:

### INVESTIGATIONS COMPLETED.

I. An investigation, by Drs. H. C. Wood and H. F. Formad, of Philadelphia, on the Etiology and Nature of Diphtheria, on which subject these gentlemen had previously submitted a preliminary paper which has been published in connection with the last annual report of the board. Their final and consolidated report is now submitted. (See Appendix 1.)

This paper recites facts and experiments of great interest in their scientific relations and in their probable bearings upon sanitary questions of vital importance to the public health. The apparently positive demonstration of the fact that a fungoid organism found in healthy and in inflamed, but non-diphtheritic throats, may yet, under certain unknown conditions, assume an active state, as shown by an unlimited power of generation in culture experiments, which is not exhibited to anything like the same extent by the innocuous form of this organism, and in this active state will give rise by inoculation to all the phenomena of malignant diphtheria, is in complete accord with parallel phenomena ascertained by the independent observations of Pasteur, Sternberg, and others, as to the identical morphological characters of harmless micrococci and of those which produce fatal septicæmia. It suggests, moreover, an analogy with the striking phenomena so recently narrated by Pasteur in his remarkable address before the International Congress in London, which phenomena he has turned to so useful an account in the protection of animals against certain malignant diseases. By inoculating sheep and cattle with the poison of charbon, attenuated by means of certain specified processes of artificial culture, he has demonstrated that this modified virus is shorn of its malignancy while it yet secures the inoculated animal from any further attack, thus greatly extending the sphere of operation of the principle involved in the immortal discovery of Jenner, and furnishing a new proof of the germ theory of disease in some of its most striking applications.

II. Experimental Investigations, by George M. Sternberg, Surgeon U. S. A., relating to the Etiology of the Malarial Fevers. (See Appendix 2.)

The experiments of Dr. Sternberg, repeating those of Klebs and Tommasi-Crudeli made in the vicinity of Rome, as a result of which they announced the discovery of a special organism which they consider to be the specific cause of the malarial fevers, seem to indicate a source of fallacy in their conclusions. Those observers seem not to have been cognizant of the fact that healthy rabbits not exposed to malarial influences, either naturally or by inoculation, do often exhibit diurnal variations of temperature (dependent apparently upon changes of external temperature or other non-malarial influence), as pronounced as those held by them to be indicative of malarial paroxysms. He further shows that the *post-mortem* appearances in the spleen, regarded by those observers to be the effect of malaria, are not in fact evidence of death from that cause, inasmuch as similar changes are found in the spleens of rabbits dead from septicæmia produced by the subcutaneous injection of human saliva. But while thus indicating the insufficiency of the evidence on which Klebs and Tommasi-Crudeli have based their conclusions, Dr. Sternberg does not feel warranted in denying the alleged relation of the fungoid organism to malarial fevers, a question which it is probable can only be fully settled by experiments on man himself.

In connection with these experiments of Dr. Sternberg, attention is invited to a special report by the same gentleman on "A fatal form of septicæmia in the rabbit, produced by the subcutaneous injection of human saliva." In this paper Dr. Sternberg incidentally narrates several facts going to show the occasional acquisition of virulent qualities by micro-organisms, which, under other circumstances, are quite harmless, and makes this important deduction:

"The fact observed by myself, that during the summer months the mud in the gutters of New Orleans possesses an extraordinary degree of virulence, shows that pathogenic varieties of bacteria are not alone bred in the bodies of living animals. The more I study this subject the more probable it seems to me that in this direction lies the explanation of many problems which have puzzled epidemiologists, and that the sanitarians are right in fighting against filth as a prime factor in the production of epidemics—a factor of which the *rôle* is easily understood if this view is correct."

III. An Investigation, by Prof. Ira Remsen, of the Johns Hopkins University, Baltimore, in relation to carbonic oxide as a source of danger to health in apartments heated by cast-iron stoves or furnaces. (See Appendix 3.)

The results of Professor Remsen's inquiries indicate possible sources of error in the well-known experiments reported by a committee of the French Academy in 1868–'69, from which the conclusion was reached that cast iron stoves, as soon as their temperature reaches dark-red heat, allow the escape of considerable quantities of the poisonous gas in question. Professor Remsen's observations go to show that in rooms heated by cast-iron stoves and furnaces there is not present in the immediate vicinity of the hot-air flues as much as 0.04 per cent. of carbonic oxide, and it remains to be shown whether such minute quantities of the gas, if present, can act injuriously on the health of those who breathe it.

IV. A Report on the Sewerage of Europe, by Rudolph Hering, sanitary engineer. (Appendix 4.)

### INVESTIGATIONS PARTIALLY REPORTED.

V. The series of investigations into the relations of different soils to the air and water currents passing through them, commenced by Prof. Raphael Pumpelly, of the U. S. Geological Survey, a year ago, have been steadily prosecuted in accordance with his plans by his able associate, Prof. George A. Smyth.

A preliminary report, dated March 28 (see Appendix 5), gives the record of the details of about four hundred experiments, involving very skillful and delicate manipulations. Numerous as the experiments have been, they form but the beginning of a series which opens up a new field of research of great practical importance.

The opinion widely entertained, that there is little or no danger of the pollution of wells by sewage leaching from cess-pools in a sandy soil, provided a moderate distance intervenes, is completely refuted by these experiments, which proves that "sand interposes absolutely no barrier between wells and the bacterial infection from cess-pools, cemeteries, &c., lying, even at great distances, in the lower wet stratum of sand." Moreover, "it appears probable that a dry gravel, or possibly a dry, very coarse sand, interposes no barrier to the free entrance into houses built upon them of those organisms which swarm in the ground-air around leaching cess-pools, leaky drains, &c., or in the filthy made-ground of cities." They also show "that a house may be built on a thoroughly dry body of sand or gravel, and its cellar may be far above the level of the ground water at all times, and it may yet be in danger of having the air of its rooms contaminated by the germs from leaching cesspools and vaults; for, if the drift of the leaching be toward the cellar, very wet seasons may extend the polluted moisture to the cellar walls, whence, after evaporation, the germs will pass into the atmospheric circulation of the house."

VI. The investigation under the direction and supervision of Prof. J.

W. Mallet, of the University of Virginia, with the co-operation of Prof. H. Newell Martin, of the Johns Hopkins University, on the best method of determining the amount of organic matter in potable water, and the specific effects of variously contaminated water on the health of persons who have used it, has now been completed so far as concerns the practical work of the laboratory. The preparation of the report will involve considerable labor and expenditure of time, and will be transmitted in connection with the next annual report.

VII. An investigation, by Mr. Ernest W. Bowditch, sanitary engineer of Boston, on the sanitary condition of summer resorts.

Mr. Bowditch had previously made for the State board of health, lunacy, and charity of Massachusetts an excellent report on the drainage of summer hotels and boarding-houses. Nearly all of those which he examined, about one hundred and fifty in number, were found to be very unsatisfactory, and threatened to become at any time foci of typhoid fever and other infectious diseases. The board was induced to invite Mr. Bowditch to extend this inquiry to Newport, Long Branch, and other places which, from the wide extent of country from which they derive their patronage, assume a national character and importance. It is a gratifying fact that for the most part the several proprietors whose premises were inspected exhibited every disposition to correct the sanitary evils discovered by the inspection.

At Newport several of the citizens, associated as a society for mutual sanitary protection, desired a more thorough survey of the city than was consistent with the general plan of the board, and agreed to pay the cost of the additional work. In this connection attention is invited to a communication addressed to the president of the board September 8, 1881, by Samuel Powel, esq., president of the Sanitary Protection Association, in regard to a grossly defective location of the quarantine of that city. That communication and the consequent correspondence with the mayor of the city and his excellency Governor Littlefield will be found in Appendix 6.

VIII. Professor Wood, of Harvard University, Cambridge, is engaged in making a special investigation into the conditions of arsenical poisoning by means of emanations from wall papers, carpets, and other furniture containing arsenical coloring matter, which will probably be completed before the close of the year.

IX. Dr. Stephen Smith, a member of this board and chairman of the committee on quarantine legislation, will, as early as practicable, make a report on the history of quarantine in the United States, intended to exhibit, as far as extant records or reliable tradition will enable him to do it, the current events which led to quarantine legislation, or attempts at such legislation, by any of the States or by the general government. In preparation for the execution of this task, Dr. Smith and the president of the board, one or both, have visited the principal ports of New England, from Newport, R. I., to Portland, Me., as also the ports of New York, Philadelphia, Baltimore, Norfolk, and New Orleans, and those on the coast of Mississippi. It is proposed to complete the tour of inspection at an early day. Additional subjects for investigation will be assigned to competent hands after the next annual meeting of the board, and will be indicated in a supplementary report.

## MARITIME QUARANTINE.

With definite and, it is believed, well matured views as to the practicability of efficiently protecting the exposed ports on the South Atlantic and Gulf coasts against the introduction of contagious and infectious diseases from foreign countries, in accordance with the requirements of the act of June 2, 1879, the board, adopting a plan proposed, and to some extent carried into execution, by the Government of France in relation to her Mediterranean ports, had at an early period of the year arranged a plan of prospective operations, involving the necessity of establishing refuge stations for infected and suspected vessels at Hampton Roads, in Virginia, at Sapelo Sound, on the Georgia coast, and in Galveston Bay, Texas, such a station having been previously established and equipped at Ship Island, in the Mississippi Sound. Estimates of the cost of construction and of maintenance for a year were submitted to Congress at the last session, but did not receive the sanction of that body, the appropriation voted for the next (the present) fiscal year being about one-third of the amount estimated by the board to be necessary if the stations in question should be established and adequately equipped.

This unexpected curtailment of the means deemed necessary for the efficient execution of the act which prescribes the duties of the board compelled the executive committee to convene a special meeting of the full board on the 2d March, to consider and prescribe for the guidance of the committee a new plan of operations in consistency with the reduction of its funds. It was then decided to abandon all the projected schemes of construction at Hampton Roads, at Sapelo Sound, and at Galveston Harbor; to operate the Sapelo Sound station with the extremely imperfect machinery in use during the last season, consisting of a boarding-tug and a few hospital tents, and to hold the hospital barge at Norfolk with a moderate equipment in reserve for the exigencies of an outbreak of infectious disease, when a contingent appropriation voted by Congress would become available.

Prior to the action of Congress the board had contracted for the repair of an old quarantine wharf and warehouse on James Island, in Charleston Harbor, South Carolina, belonging to the United States, but used by the quarantine authorities of the State.

The various structures previously erected at Ship Island, namely, a wharf, a capacious warehouse, a hospital for the sick, a suitable building, remote from the hospital, for the accommodation of persons not sick with any infectious disease, but kept for a time under observation as having been on infected vessels, and finally very modest quarters for the medical officers, have all been completed. These buildings, together with the vessels necessary for the service in connection with the station, have been provided at the small aggregate cost of $30,000.

These several structures, in strict conformity to the letter of the law, are "temporary," in the sense of being built of wood and other inexpensive materials, but the hospitals and other houses are commodious and admirably adapted in a mild and semi-tropical climate to the uses for which they were designed, and, although intrinsically perishable, may be kept in a condition of usefulness at a small annual cost of repair.

It is a source of deep regret to the board that the limitation of its resources imposed by the recent action of Congress precludes the possibility of making an equally efficient arrangement at the other named localities on the South Atlantic and Gulf coasts, and thus of preparing adequate safeguards against the introduction of infectious fevers from foreign countries through any of the ports of the United States, from Baltimore to the southern limit of the coast of Texas. Baltimore is named in this connection because although possessing a full equipment of quarantine machinery, which will always be needed for the purpose of quarantine inspection, it is to be presumed that the authorities of that port will be glad to avail themselves of a refuge station in Hampton Roads, to which they may send infected vessels, and thus avoid the danger of communicating infection to other shipping, whether vessels *in transitu* to the wharves of the city or such as are under observation atthe quarantine anchorage in dangerously close proximity to the city. It would be desirable to establish a similar station of refuge at or near the Delaware Breakwater, for the protection of Wilmington and Philadelphia. Further north the elaborately equipped quarantine stations of New York and Boston are so situated as to enable them already to fulfill this office, both for their own ports and those of neighboring States. That the station at Ship Island and other similar stations which the Board intended to establish may justly be characterized as "adequate safeguards" against the introduction of infectious diseases into any of the ports of entry which will co-operate with the National Board of Health in its efforts to secure such a result, seems to be sufficiently attested by the experience of this summer. Four yellow-fever ships have been received and treated at Ship Island during the summer, the same having been sent thither by the quarantine authorities of Pensacola, Mobile, and Pascagoula. No death has occurred among the cases received into hospital, and no case of fever has occurred upon either of the vessels after they were released, or in any port where they have subsequently touched. It may be remarked in this connection that, owing to the extent of anchorage ground off Ship Island it has been found practicable to aid the health authorities of the several ports of Hancock and Harrison Counties, Mississippi, namely, Mississippi City, Pass Christian, Bay Saint Louis, and Shieldsborough, by assigning a part of said anchorage, distant over two miles from the anchorage for infected vessels, as an inspecting station for said ports. Their trade is not of sufficient extent to enable them to bear the expense of establishing and maintaining such a station, which is indispensable to the safety of the whole country, inasmuch as a single infected vessel coming into one of these ports might as readily originate a focus of infection, whence the disease might spread over the entire region, as in the case of ports of larger trade. This aid is rendered through the instrumentality of the medical officer at Ship Island, with little or no additional cost to the government.

The report of Dr. T. S. Scales, superintendent of the station, hereto appended (Appendix 7), gives further interesting details.

The Sapelo Sound station, located on Blackbeard Island, with its very scant and imperfect machinery, has yet proved to be a very important means of defense to the South Atlantic ports. The authorities of Fernandina, Brunswick, Darien, Savannah, and Charleston have all issued orders to pilots prohibiting the admission into their respective ports of infected vessels, namely, such vessels as have suspicious cases of disease on board, or on which such diseases have existed during the voyage, until the masters of such vessels shall produce a certificate from the superintendent at the Sapelo refuge station that they have been properly and effectively cleansed and disinfected and are now probably free from infection. Four such vessels were received and treated by Dr. W. H. Elliott, medical superintendent of the station, who has accomplished, under circumstances of great difficulty and personal discomfort, all that was practicable with the means furnished him. Details will be found in his report (Appendix 8).

The only locality in the United States in which a case of yellow fever has occurred *on shore* during the summer just ended was at Key West. For a notice of the peculiar and exceptional position of that place, reference is invited to the statements made in the second annual report of this Board, and to a report by Dr. S. M. Bemiss, a member of the Board, of a recent sanitary inspection made by him under the orders of the executive committee. (See Appendix 9.)

The case of Key West is a peculiar and exceptional one, and, for reasons set forth in the report of Dr. Cochran, a sanitary inspector of this Board, a copy of which will be found in the appendix of the last annual report, the Board did not consider it necessary or expedient to report the facts to the President of the United States with a view to the establishment of a compulsory quarantine in conformity with the provisions of section 3, of the act approved June 2, 1879, to prevent the introduction of contagious and infectious diseases into the United States. The cost of such an establishment would probably be disproportionate to the resulting benefits in view of the comparatively slight danger of the transmission of the infection from that city, except by sea-going vessels which, if bound to other United States ports, can be quarantined at the ports of final destination. In view, however, of the frequently recurring introduction of yellow fever into Key West, and the refusal of its authorities to apply measures of quarantine, this Board has considered it to be its duty to advise the health authorities of all ports having communication with Key West during warm weather to take special precautions in dealing with vessels from that port.

As a part of the machinery by which the Board has attempted to facilitate the work imposed by the law of June 2, 1879, on the consular officers of the United States at foreign ports where infectious diseases habitually prevail, it has kept a competent medical officer, Dr. D. M. Burgess, on constant duty in the office of the consul-general at Havana. The services rendered by this gentleman and by Consul-General Hall have been such as to merit the highest commendation, and the practical results have been highly beneficent.

### INTER-STATE QUARANTINE.

For reasons which have been heretofore stated at length, the Board had maintained during the summers of 1879 and 1880 a very efficient system of river sanitary police on the Mississippi River, by means of fixed stations for quarantine inspection, at several points between New Orleans and Cairo, as specified in former annual reports; and also of a fast sanitary patrol boat for rapid communication with localities recently infected, or supposed to be infected, for carrying medicines and other supplies, and for transporting the sick to the hospital flats moored at the fixed stations, whenever it should become necessary to depopulate a village in which infectious disease had broken out. The attention of Congress was invited in the last annual report to convincing proofs of the great value of this system, furnished by the testimonials incorporated in the report of Dr. R. W. Mitchell, a member of this Board, and at that time the director of the service in question.

With such evidences of its utility, the Board was desirous of extending and perfecting this service for the present year, and made estimates accordingly, but the smallness of the appropriation caused the Board no little anxiety as to its ability to do anything more than to put the several stations in a state of readiness for commencing operations in the event of the appearance of yellow fever at or below New Orleans. At first it was decided to act on such a basis, but it was soon found that the apprehensions entertained all along the Mississippi Valley as to the probability of an invasion of yellow fever were such as to make it absolutely certain that a rigorous quarantine would be established against

New Orleans, producing vexatious and costly interruptions to trade and travel. The authorities of Vicksburgh and those of Memphis had, indeed, published ordinances prohibiting the landing of either persons or merchandise from New Orleans without a certificate from the inspecting agents of the National Board of Health at these river stations. The Board accordingly, at its semi-annual meeting in June, decided to renew the service on as moderate a scale of expenditures as was consistent with the attainment of the objects in view.

The report of Dr. F. W. Reilly, superintendent of this service, furnishes the details of the work of the season. (See Appendix 10.)

### SANITARY INSPECTIONS AT NEW ORLEANS.

The service of sanitary inspections of river craft and railroad running stock and freight at New Orleans during the summer months is closely connected with the operations of the Mississippi River inspection service, and is still more important, inasmuch as absolute perfection of the former, were this attainable, would supersede the necessity of further inspections above. Unfortunately, such perfection is not attainable, but there may be an approximation to it, and the agency which secures this has a value which cannot be overestimated. This branch of the preventive service, during the summer of 1881, has been under the direction of Dr. S. E. Chaillé, whose vigilance and energy have been unremitting, and have been productive of beneficent results, as will appear by the facts cited in his report. (Appendix 11.)

The consideration of the several recommendations contained in his report, and the appendices thereto, will engage the attention of this Board at the approaching annual meeting in December.

### INTRODUCTION OF SMALL-POX INTO THE UNITED STATES.

At an early period of the summer, the health authorities of New York, Michigan, Indiana, Illinois, Iowa, Minnesota, and Wisconsin, being impressed with the evidences of the alarming prevalence of small-pox in the Western and Northwestern States, met in conference at Chicago, on the 29th and 30th June, to consider what measures should be taken to prevent further importations of the disease and to stamp out the existing local epidemics. It was conclusively shown that the disease was for the most part introduced by emigrants from Europe taking passage at ports where it was known to exist, and where, consequently, persons coming from the interior were exposed to the contagion in cheap lodging-houses immediately before sailing. Owing to the length of the period of incubation the disease is seldom manifested until after the emigrants have passed quarantine inspection at the ports of arrival and have proceeded thence to their several destinations in the Western States, where they initiate local epidemics in numerous localities.

The conference passed resolutions calling upon the National Board of Health to aid the State health authorities, in conformity with the provisions of the act of June 2, 1879, to prevent the introduction of contagious and infectious diseases into the United States from foreign countries, and from one State to another. The executive committee accordingly felt constrained to call a special meeting of the full Board, in order to revise the rules and regulations heretofore approved by the President of the United States for securing the best sanitary condition of vessels, including their cargoes, passengers, and crews, coming to the United States from any foreign port where any contagious or infectious disease exists, and to make such modifications as would serve to render these regulations available for the prevention of the introduction of small-pox into the country. They had been originally prepared with reference to other infectious diseases. It was also desired to consider the propriety of reporting to the President the fact that there is no adequate provision by State or municipal legislation, in any of the ports of the United States, for the effective application of preventive measures against the introduction of small-pox, and of soliciting his intervention in the manner prescribed in section 3 of the same act.

At this special meeting, held July 28, the Board found the evidence of the frequent importation of the contagion by emigrants from Europe to be fully conclusive, and that the consequences were such as to justify the demand made by the health authorities of the States referred to and to call for prompt and energetic action. Accordingly the Board adopted a revised system of rules and regulations to be observed at foreign ports for securing the best sanitary condition of vessels, including their cargoes, passengers, and crews, coming to the United States from such ports, the principal feature of which was the incorporation of a new rule requiring the vaccination of all unvaccinated emigrants about to embark for the United States from any foreign port or place in which small-pox exists.

At the same time, in a separate communication, the President was respectfully requested to approve a draft of "Additional rules and regulations to supplement the defective rules of local boards of health, in respect to the measures to be adopted at the home ports for preventing the introduction of small-pox into the United States."

These additional rules and regulations require the vaccination of unprotected emigrants arriving at any of the ports of the United States from places where small-pox exists, or in the contingency of their refusal to be vaccinated, then their detention in quarantine until sufficient lapse of time after their exposure to insure their freedom from contagion. These papers were submitted to His Excellency September 29.

The several papers alluded to in this statement will be found in Appendix 12.

## INTERNATIONAL SANITARY CONFERENCE AT WASHINGTON.

A joint resolution of the Senate and House of Representatives, approved May 14, 1880, authorized the President "to call an international sanitary conference to meet at Washington, District of Columbia, to which the several powers having jurisdiction of ports likely to be infected with yellow fever or cholera shall be invited to send delegates, properly authorized, for the purpose of securing an international system of notification as to the actual sanitary condition of ports and places under the jurisdiction of such powers, and of vessels sailing therefrom."

As this joint resolution had its origin in a recommendation of this Board, contained in its first annual report, it is considered admissible to refer very briefly to the conclusions of the conference which, with the several protocols, have been submitted to the Senate. When these shall have been published it will be seen that the scheme adopted by a majority of the conference is somewhat more elaborate and cumbrous than the plan recommended by the American delegates who represented the views of this Board. It is also believed to be less likely to be practically efficient than the simple measures advocated by these delegates. Nevertheless, if adopted and faithfully executed by the governments interested, incalculable good will have been achieved. If objected to on the grounds of probable inefficiency or for any other cause, the governments will have an opportunity of considering an alternative proposition, which, presented by the French minister in a spirit of compromise, approximates in simplicity and capability of easy execution to that suggested by the American delegates.

By one of the provisions of section 4 of the act approved June 2, 1879, the Board of Health is required not only to make an annual report of its operations, but also such recommendations as it may deem important to the public interests. For the discharge of this part of its duty it is respectfully requested that permission be granted to make these recommendations in a supplemental report, to be sent in for transmission to Congress at an early period of the session. At the last general meeting of the Board the fiscal year for which the Congressional appropriation had so recently been made had not get commenced, and it was not possible to foresee wants which would largely depend upon the incidents of the summer just then beginning. Accordingly no action in this direction was taken at that time. The next general meeting of the Board will be held early in December, and its recommendations may then be incorporated in a supplemental report, which will be ready for transmission in time to be delivered to the Public Printer as a part of the general report.

## ESTIMATES AND EXPENDITURES.

The following statement of expenditures for the year ending June 30, 1881, is respectfully submitted.

*Statement of the expenditures of the National Board of Health for the year ending June* 30, 1881, *by quarters and in detail, together with the expenditures from organization of the Board to June* 30, 1881.

| On what account. | Total for quarter ending September 30, 1880. | Total for quarter ending December 31, 1880. | Total for quarter ending March 31, 1881. | Total for quarter ending June 30, 1881. | Total expenditures for the year ending June 30, 1881. |
|---|---|---|---|---|---|
| Floating quarantine on Mississippi River | $9,988 39 | $8,339 21 | $3,210 09 | $16,489 79 | $38,027 48 |
| Ship Island quarantine | 11,737 28 | 10,777 10 | 2,016 89 | 8,768 54 | 33,299 31 |
| Blackboard Island quarantine | 2,167 42 | 1,782 11 | 107 00 | 5,822 78 | 10,479 31 |
| Elizabeth River quarantine | 2,317 75 | 240 00 | 434 65 | 254 14 | 3,246 54 |
| Aid to Pensacola, Fla | 3,195 63 | 1,066 59 | 120 00 | 62 66 | 4,444 88 |
| Aid to Pascagoula, Miss | 97 58 | 71 79 | | | 169 28 |
| Aid to Hancock County, Mississippi | 319 35 | 300 00 | | | 619 35 |
| Aid to Harrison County, Mississippi | 353 70 | 413 20 | | | 766 90 |
| Aid to State board of health, Louisiana | 1,490 00 | 411 90 | | | 1,901 90 |
| Aid to State board of health, Texas | 125 00 | 150 00 | | | 275 00 |
| Aid to Charleston, S. C | 40 20 | 1,114 25 | 1,822 87 | 3,704 00 | 6,681 30 |
| Havana Commission | 662 30 | | | | 662 30 |
| Pay and expenses inspectors at Havana, Memphis, &c | 5,069 15 | 2,051 00 | 2,777 52 | 1,400 25 | 11,357 92 |
| Special scientific investigation | 849 73 | 1,900 33 | 1,695 41 | 5,731 46 | 10,176 93 |
| Pay and expenses members of the Board | 2,559 20 | 1,938 08 | 2,185 15 | 2,163 44 | 8,845 87 |
| Storage of tents, &c | 260 75 | | | 52 60 | 313 35 |
| Printing of the Bulletin of the National Board of Health | 2,147 89 | 2,131 05 | 1,285 87 | 2,637 46 | 8,202 27 |
| Printing of blanks, &c | 172 65 | 58 07 | 380 35 | 315 21 | 926 28 |
| Pay of clerks, messengers, &c | 4,450 39 | 4,448 99 | 4,867 19 | 4,849 99 | 18,656 56 |
| Rent, light, and fuel | 212 40 | 330 80 | 340 80 | 627 83 | 1,511 83 |
| Telegrams | 96 11 | 89 52 | 36 17 | 100 73 | 322 53 |
| Furniture, stationery, &c | 765 80 | 280 98 | 279 18 | 1,368 82 | 2,694 78 |
| Miscellaneous expesses National Board of Health | 242 86 | 270 03 | 236 12 | 408 47 | 1,157 48 |
| Postage | | | 36 50 | 213 59 | 250 09 |
| Total | *49,921 53 | *38,204 91 | 21,831 26 | 55,031 76 | 164,989 49 |

| | |
|---|---|
| *From the date of organization of the Board (April 1, 1879) to June 30, 1879, there was expended | $9,146 41 |
| *From June 30, 1879, to June 30, 1880, there was expended | 266,762 16 |
| From June 30, 1880, to June 30, 1881, there was expended | 164,989 46 |
| Total amount expended by the Board from date of organization to June 30, 1881, inclusive | 440,89 803 |

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*Detail statement of these expenditures heretofore reported to Congress.

It should be observed that no part of the contingent appropriation of $100,000 which was to be available in the event of an outbreak of epidemic disease has been touched.

It is requested that this amount be reappropriated under the same conditions for the next fiscal year.

The estimates of appropriations required for the prosecution of the work of the Board during the next fiscal year have heretofore been transmitted to you, and are embraced in the book of estimates of appropriations for the fiscal year ending June 30, 1883.

The attention of Congress is respectfully called to these estimates, and it is hoped they will receive favorable consideration.

Very respectfully,

J. L. CABELL,
*President National Board of Health.*

T. J. TURNER,
*Secretary National Board of Health.*

# APPENDICES.

# REPORTS AND PAPERS.

# APPENDIX No. 1.

## *REPORT ON DIPHTHERIA.*

[BY DRS. H. C. WOOD AND H. F. FORMAD.]

## PREFACE.

During the spring, summer, and autumn of 1880 the work forming the basis of the following report was prosecuted very actively, and the results obtained were published by the National Board of Health. Last March we resumed our labors, and have done all that we could during the summer. In the winter it is almost impossible for us to get time for original research; and although the etiology of diphtheria cannot yet be considered as thoroughly worked out, it has been thought best to present our report upon what has been accomplished, and in the report to embody that portion of the work of 1880 which is logically necessary to the completed whole. It has also seemed to us that our monograph would be much more valuable and effective if we should collect the scattered, and to very many physicians inaccessible, literature of the subject. We have therefore prefaced the main text with an introduction which is thought to contain an epitome of all that has been hitherto discovered concerning the relation of low organisms to diphtheria.

We desire here especially to express our thanks to Dr. P. P. Short, of Ludington, Mich. It was only through his strenuous exertions that it became possible to study the Ludington epidemic.

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## CHAPTER I.

### BIBLIOGRAPHICAL INTRODUCTION.

### (A.) IN FAVOR OF THE FUNGOID ORIGIN OF DIPHTHERIA.

**OERTEL** (*Studien über Diphtheria*, Arztl. *Intelligensblatt*, 1868, No. 31) was the first to speak of micrococci as occurring in diphtheritic pseudo-membrane, and also in the blood, the lymphatic vessels, and the kidneys of persons affected by diphtheria. He describes them as "point-like, dark-contoured, round or oval (immovable)" little bodies, occuring either isolated or in zooglæa form. Later (*Deutsches Archiv f. Klin. Medicin.*, 1871, p. 242, and in *Ziemssen's Encyclopædia*, 1874), Oertel desbribes the diphtheritic fungi to be spherical bacteria (micrococci, accompanied by a larger or smaller quantity of bacterium termo). He thinks that they are the direct cause of the diphtheritic inflammation; that long before any false membrane is formed they attack the mucous membrane and induce the disease.

Oertel experimented as follows:

*First series.*—Produced ammonia croup in rabbits; found few or no micrococci in the false membrane, and never any in the blood and organs. Hence he thinks that croup must be strongly separated from diphtheria.

*Second series.*—He inoculated with true diphtheritic matter in the trachea, twelve rabbits, three pigeons, and two chickens; and produced local lesions and constitutional disturbances perfectly identical with those of diphtheria in man; micrococci were found abundant in the blood of the poisoned animals.

*Third series.*—He inoculated rabbits with true diphtheritic matter, placing the poison below the skin and in the muscles, with the same results as in the second series.

*Fourth series.*—He inoculated rabbits with pyæmic pus and gangrenous tissues with negative results.

*Fifth series.*—He succeeded by inoculations in the trachea in transmitting the disease—

1st. From man to rabbit No. 1.
2d. From rabbit No. 1 to rabbit No. 2.
3d. From rabbit No. 2 to rabbit No. 3.
4th. From rabbit No. 3 to a pigeon.
5th. From the pigeon to rabbit No. 4.

All the animals died with lesions peculiar to diphtheria within thirty to forty hours.

How the bacteria acts he says is not known.

Oertel further affirms that the quantity of fungi present in any case bears a direct relation to the intensity of the morbid process; they multiply as the disease advances and diminish with its retreat. Also that the special form of fungus is never present in simple inflammation of the fauces or in mercurial stomatitis; but that, if the diphtheritic process intervenes on these disorders, the fungus at once makes its appearance, and quickly displaces the more common forms of bacteria which are present.

NASSILOFF (*Virchow's Archiv*, vol. 50, 1870), from his observations and experiments, came to the conclusion that the fungi found in diptheria are identical with those occuring in decomposing animal tissues. His conclusions are:

(1.) Fungi are always present in diphtheritic membranes.

(2.) The development of the fungi precedes the formation of the membrane, and the fungi are the direct cause of the necrotic changes in diphtheritic inflammations.

(3.) The fungi penetrates into the tissues by way of the juice channels and lymphatics before any changes in those tissues can be observed, so that fungi are the cause of the inflammation and the destruction of the parts affected.

HUETER AND TOMMASI (*Med. Central Blatt*, 1868, No. 12 and 34), also established by experiment the direct causative relation of micrococci to diptheria. They placed particles of diphtheritic membranes in the muscles of the back of rabbits. Death followed promptly within forty hours. The tissues at the seat of inoculation were inflamed and invested by very small, roundish micrococci. The latter were found also during life in the blood of the infected animals.

TRENDELENBURG (*Arch. f. Klin. Chirurgie*, 1869, vol. 10) put diphtheritic matter in the trachea of rabbits and pigeons. He succeeded in producing false membrane only in eleven out of sixty-eight experiments; in the blood of rabbits inoculated with diphtheritic matter he frequently found micrococci, sometimes even in those animals in which a distinct false membrane had failed to appear. Frequently, but not always, he found micrococci in the blood of children suffering from the disease.

Trendelenburg doubts whether the micrococci, as found in the blood of diptheritic patients, are peculiar to diphtheria, and does not believe it to be a proof of the transmission of diphtheria to animals if at the seat of inoculation a diphtheritic inflammation is produced.

EBERTH (*Correspondenz-Blatt der schweizer Aerzte*, No. 1, 1872) discovered in 1871 micrococci in the blood and the tissues of persons who had died of diphtheria, but was not able to detect the fungi in the blood or even in the false membrane of patients suffering from true croup.

Experimentally he succeeded in reproducing diphtheria in animals, which died in three days.

Diphtheria of wounds, Eberth thinks, stands in close relation to pyæmia. Pyæmia, he says, "is a diphtheria proceeding from a wound." The bacteria of diphtheria and pyæmia he believes to be identical.

LETZERICH (*Virchow's Archiv*, 1873, vol. 58) claims to have produced local and general diphtheritic lesions with the fungi filtered out from the urine of individuals suffering from that disease. When the dried urine filter, with the pure fungi on it (all other foreign matter having been washed out by means of hot water), were introduced into the uninjured mouths or vaginas of rabbits, diphtheritic pseudo-membranes and death followed in from three to five days.

He describes the fungus as occurring in four forms.

First. Constituting small balls composed of a hyaline substance, which is colored blue by iodine and sulphuric acid, and of small punctiform roundish or elliptical little bodies, which may increase until the whole mass becomes very dark.

Second. Large balls "*Plasmakugeln*" with a seeming outer membrane.

Third. Large irregular masses formed by the bursting of these balls.

Fourth. True mycelial filaments which produce spores of a tilletia, and are named by Letzerich *Tilletia diphtheritica*.

COHN (*Beiträge zur Biologie der Pflanzen*, 1872 and 1873), who regards bacteria as algæ, classes the diphtheritic plant with the schizophytes; tribe, sphaero-bacteria, and calls it *Micrococcus dipththeriticus*. He gives as its specific character: Perfectly round, less than one micromillimeter in size; in multiplying, first forms in pairs, then several joints, then chains, and finally zooglaea masses, but never any mycelium.

KLEBS (*Correspondenz-Blatt der schweizer Aerzte*, 1871, No. 9) thinks that micrococci do develop a *mycelium* resembling *Leptothrix buccallis*, but somewhat thinner or more delicate than it is. This diphtheritic mycelium forms on the surface of affected membranes dense bunches upon which spores are produced. The latter collect in masses in zooglaea form of various size and shape. Between these groups occur free micrococci ("*Monades*"), micrococci chains, and rod bacteria. The greatest destruction of tissues is produced by the zooglaea.

Klebs agrees with Eberth concerning the identity of diphtheritic and septic micrococci. In his latest publication (*Archiv für Experiment. Pathologie, und Therap*, Vol. 4, p. 191), Klebs describes the diphtheritic fungi as follows:

*First stage.*—Very small micrococci forming in the quiescent state sharply defined round balls, the individual micrococci being united in rows or chains and imbedded in a very scanty gelatinous matter.

*Second stage.*—Peripheral layers of the micrococci balls give rise to mobile bacteria, which do not need much oxygen, and have a tendency to penetrate into and live within the tissues and juices where not much oxygen is present.

*Third stage.*—The highest form of development consists in the formation of a mycelium in the tissues. The threads are never branching, and arrange themselves parallel to one another, covering the outer surfaces like the grass in the turf. Occasionally mycelium masses may form in deeper structures of the organisms.

Professor Klebs also gives the following as peculiarities in the life-history of the diphtheritic fungus:

(*a.*) They can grow and develop without oxygen.
(*b.*) They are killed only by a temperature of 65° to 70° C. (Not below that.)
(*c.*) In themselves they do not develop any fœtid gases.
(*d.*) They are sometimes of intensely yellow color.
(*e.*) They may circulate in the blood, but preferably are deposited outside the blood-vessels, where they may form mycelial masses.

They never penetrate into the substances of the epithelial cells, but go between them (Klebs and Eppinger). They afford a distinction between diphtheritic and inflammatory croup.

M. CH. TALAMON describes a fungus as the true diphtheritic poison, which has a remarkable resemblance to a penicillium. We quote from a translation in the *Chicago Medical Examiner*. He says he has cultivated it in damp cells, and that after its evolution is completed, it appears under the shape of mycelia and characteristic spores. These mycelia sometimes appear as long tubes, partitioned from distance to distance, specially refracting the light, and generally very clear; they are from 2 to 4 and 5 thousandths of a millimeter wide (.000002 to .000005). When the fluids are well conditioned they stretch extremely, at times branch off, and these divisions are themselves peculiar; they form by their slightly incurved branches a figure best compared to a lyre or a tuning fork. At other times, the mycelia do not stretch in this way, although multiplying so as to rapidly cover the surface of the liquid of cultivation, they remain short, take on odd shapes, the most common of which resemble a crutch; there is always present then a multitude of straight cylinders, 4 or 5 thousandths of a millimeter wide by 15, 20, or 40 thousandths long (.000004$^{m}$ by .00005$^{m}$ or .00004$^{m}$.)

There are two kinds of spores—round or oval—which may be considered the spores of germination, and rectangular spores, which represent the last phase of growth of the fungus, and which we will call conidia (conidies). These give the species its particular character; their shape is rectangular and their size very liable to vary; their width varies from m. .000005 to .000015. Sometimes they are isolated, other times they are in groups of 2 or 3; often they form beads of 10, 12 or 15 individuals, or a small chain in zigzag. Homogeneous at first, they soon become filled with small, round bodies, very brilliant, the size of common micrococci, which appear to me as the true germ of the fungus.

The round or oval spores form the mycelium by stretching; they look like bright specks m. .000003 to .00005 in diameter, in the middle of granular matter, spread in sheets of greater or lesser extent, which represent what is called zooglea. The spores stretch one of their poles so as to form a tube m. .000002 to .000004 in diameter, which branches as above stated. When the lengthening of the mycelium is first begun, the space with its prolongation represents a tadpole. Mr. TALAMON claims to have produced diphtheria in rabbits, guinea pigs, cocks, and pigeons, by inoculating with this fungus, and even some frogs who were fed upon the fungus promptly succumbed to the disease.

### (B.) AGAINST A FUNGOID ORIGIN OF DIPHTHERIA.

SENATOR (*Berliner Klin. Wochenschrift*, 1872, Nos. 26, 27, 31, and 33, and *Volkmann's Sammlung Klin. Vorträge*, 1874, No. 78) delares himself decidedly against a fungoid origin of diphtheria, on the following grounds:

Other diseases of the mouth and the pharynx are accompanied by the same micrococci, which are also found in the mucus between the teeth and in the urine of the normal man, micrococci being only the spores of leptothrix bucallis. The diphtheritic micrococci do not differ in cultures in any way from those of other origin.

*Experimental proof.*—Inoculations with any putrefying substances have given the same local and secondary changes as those produced by true diphtheretic material.

Scarlet fever produces precisely identical local lesions in pharynx as those which occur in diphtheria.

Micrococci multiply enormously on account of the favorable conditions in the pharynx created by the deep-seated ulceration: when ulceration is absent, as in the larynx the micrococci are in only very moderate number; probably the carbonic acid is exerting also some antiseptic effect in the latter case.

BILLROTH (*Untersuchungen uber Vegetationsformen der Cocco-bacteria Septica, &c.*, Berlin, 1874), who investigated the bacteria question exhaustively, came to the conclusion that they are only concomitant with diseases, and expresses himself positively against the view that the different affections are caused each by special forms of bacteria. He says that the so-called pathogenic bacteria of diseases are positively identical with those found in putrefying dead tissues.

LEBERT (*Ziemssens Handbuch der acuten Infectiouskrankheiten* vol. 1, p. 255) is also against the fungoid theory, on the ground that nothing has yet been proven.

WAGNER thinks there is a great difference between the human pseudo-membrane and the experimentally-produced false membrane.

BEALE (Disease d germs, London, 1872) denies specific fungi altogether.

NAGELI thinks that all varieties of bacteria are derivatives of one and the same species of fungi.

Dr. JACOBI, of New York, also entirely dissents from the fungal origin of diphtheria.

Dr. C. HARLEY (Pathol. Transact., vol. x, p. 315) failed to inoculate animals with diphtheritic membrane.

In a very able study of the subject Drs. SATTERTHWAITE and CURTIS (Report of Dr. Edw. Curtis and Thos. Satterthwaite to the New York City board of health, New York, 1877) are also opposed to the fungal theory, on account of the following facts and deductions, founded upon their own researches.

First. The bacteria of diphtheritic membranes do not differ in optical or chemical behavior from those found in putrescent but non-diphtheritic animal material.

Second. They believe the disease produced in rabbits by diphtheritic inoculation is not diphtheria, and find that "Scrapings from the upper surface of a somewhat furred tongue from a healthy person" produce, when placed in the cellular tissue of the rabbit, symptoms and results exactly similar to those caused by inoculations with diphtheritic membrane; also that inoculations of rabbits with putrid Cohn's fluid produce similar results to those.

Third. Salicylic acid added to the diphtheritic matter does not prevent its action, although, as they believe, it acts fatally upon the germs.

[This last objection is not, as it seems, a conclusive reason, for it is very possible that salicylic acid may arrest the growth of micrococci without killing them. In the experiments of Curtis and Satterthwaite, it was shown that before the injection the micrococci did not grow in the presence of the salicylic acid; after the injection the salicylic acid is undoubtedly removed from the injected material by being absorbed into the system, the micrococci remaining largely at the seat of inoculation. Under these circumstances if the micrococci were only benumbed, not killed by the acid, they would of course soon begin to grow and assert themselves.]

## CHAPTER II.

## STUDIES UPON THE HUMAN SUBJECT.

In the introductory summary we have given an epitome of the results obtained by all of the investigators as to the relations of bacteria to diphtheria, with whose work we are familiar. In the following pages we will confine ourselves more or less closely to our own studies. These have been made from a double point of view, namely, clinical and experimental. The first question which naturally presents itself is, are the bacteria, which are always present in the false membrane of diphtheria, identical in form and size with those which are present not only in the membrane of a non-diphtheritic trachitis, but also in the exudation of an inflamed tonsil? We do not hesitate in affirming that it is not possible to determine, even with the highest powers of the microscope, whether an individual micrococci colony or a mass of such colonies have come from the surface of a furred tongue or from an ordinary case of simple throat inflammation, or from one of a diphtheritic character. As evidence of this we offer the following microphotographs, one taken from an undoubted case of diphtheria, the other from an inflamed throat.

A second question, no less important than that just discussed is, are bacteria always present in diphtheria, or only in some cases? The vital nature of this query scarcely requires pointing out; if bacteria are really always to be found in the disease it is very probable that they are at least an essential part of it; on the other hand, if they are only occasionally present it is most probable that they are an accident of the affection.

In attempting to answer the question just propounded we have examined a large number of cases. Without further discussion, we desire once for all to state that every precaution has been taken to make the examinations at once careful and exhaustive.

The cases examined are naturally divided into two sets, according to their geographical and epidemic relations: one of these sets (No. 1) represents what we may be allowed to call endemic or sporadic diphtheria: the other series (No. 2) illustrates true malignant epidemic diphtheria. In the city of Philadelphia there are always more or less numerous cases of the disease of varying type as to severity, but at no time during our studies has there been anything which could properly be termed an epidemic of diphtheria. Cases of set No. 1 were all observed in Philadelphia or its vicinity.

The town of Ludington, situated on Pere Marquette Lake upon the east shore of Lake Michigan, in the State of Michigan, is a center for the lumber trade, and an enormous amount of sawdust is annually produced there. A part of the town is situated upon a high plateau, but the third ward, bordering upon the lake, is built upon a swamp, which has been filled largely with the great staple of the place, *i. e.*, sawdust. The drainage is so bad that in many places a hole dug a couple of feet in the ground soon fills with water, and only in a small percentage of the houses has any attempt been made to construct cellars. During the winter of 1880 and 1881 diphtheria appeared in this low region and spread with such thoroughness that it is said scarcely a child escaped an attack, and about one-third of them died. Dr. Formad was sent in the month of June to Ludington and made studies there of the disease, with especial reference to the micrococcus question. The cases there studied constitute set No. 2, and may be fairly considered to represent the most malignant form of the disease.

### SET NO. 1.

CASE I.—Boy, three years old, under the care of Dr. Schrotz. He took the disease simultaneously with two other children, and died on the fifth day, chiefly from asphyxia. The membrane appeared first in the pharynx.

*Autopsy.*—Blood taken by sealed glass tubes* from jugular vein eighteen hours after death contained micrococci; organs not examined; false membrane from larynx used for culture.

CASE II (Dr. Campbell).—Girl, eighteen years old, with profuse exudation on tonsils and pharynx and extending into nasal cavity. Blood from finger did not contain micrococci.

CASE III (Drs. Griffith, Middleton, and Zerns).—Boy, six years old, took the disease June 26. Exudation first appeared in the pharynx and afterwards extended into the larynx. Blood examined July 1 and July 2, and at 10 a. m. July 4. Contained no micrococci. The last examination was made by both of us, conjointly. Child died 12 noon July 4. The cause of death was suffocation from stenosis of the larynx.

*Autopsy, thirty hours after death.*—Blood taken from jugular by means of sealed tubes contained micrococci, both in masses and attacking the white blood cells.

Rigor mortis not marked; no signs of decomposition. Face and neck were of dark bluеish hue. All the veins of the neck were enormously distended by very dark blood. Salivary and cervical lymphatic glands strongly congested and somewhat enlarged. Larynx and trachea were almost completely obstructed by moulds of false membrane, the latter extending into many of the bronchi. The mucous membrane of the upper anterior portion of trachea showed several shallow necrotic ulcerations. The vocal cords were thickly covered with closely adherent pseudo-membrane. Lungs congested and œdematous; several hemorrhagic infarctions at the periphery of lower lobes. Pericardium and pleura congested. Heart: right side filled with large ante-mortem clots, extending into pulmonary artery and its ramifications. Orifices and endocardium normal. Liver, kidneys, and spleen strongly congested; microscopic examination did not show any other lesion than cloudy swelling, and proved *absence of micrococci.* Stomach empty, and, like the intestines, was much distended by gases, and the mucous membrane of both congested. Other abdominal viscera normal. Examination of tongue, pharynx, and brain was not permitted.

CASE IV (Dr. Gibbs).—Boy, eleven months old, admitted to the Philadelphia Hospital, July 7, with considerable membrane in the pharynx, and marked febrile disturbance. The blood showed abundant micrococci in large vesicles, about twice the size of white blood corpuscles, out of which they were apparently formed.

*July* 8.—Blood showing similar appearances as on the 7th.

*July* 11.—Child much better. Blood containing few micrococci.

*July* 13.—Child well. Blood showing no signs of micrococci.

CASES V, VI, VII.—Respectively, boy three years old, boy five years old, and girl seven years old, treated at Philadelphia Hospital. The symptoms were abundant false membrane in the pharynx, not extending into trachea, with prostration and fever. All recovered. The blood of each was examined twice but no micrococci were found.

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*A small glass tube closed at one end was drawn to a point hermetically closed whilst hot. The sharp point thrust into the jugular vein was broken off and blood drawn up into the tube.

Case VIII.—Boy, nine years old. The membrane in pharynx was slight, but in the larynx and trachea profuse. The child died, on the eighth day of the disease, of asphyxia from laryngeal stenosis. The blood examined twenty-four hours before death contained no micrococci. No autopsy was allowed.

### Set No. 2—(Ludington Cases.)

Case I.—Boy, five years old, no strong constitution, died of prostration on the fifth day of the disease, at which time the false membrane, which at first was profuse, had lessened very much, so that there was no serious mechanical obstruction to respiration. Suppression of urine came on thirty-six hours before death. The blood examined during the second day of the disease showed micrococci in moderate quantity; a few attacking white blood corpuscles. Third day of disease micrococci in the blood much more abundant, very many of the white corpuscles attacked by them. Fourth day, masses of micrococci free in the blood, the white corpuscles almost all affected. Fifth day, blood very dark in appearance, clotting very rapidly, full of micrococci, no white corpuscles free from the fungus. Half an hour before death blood was taken from the finger (which was very cold); it was very dark, coagulated almost instantly, and offered but few micrococci. It was then taken from the thigh, where the temperature was still high, and was found to be gorged with micrococci.

*Autopsy twelve hours after death.*—

Body of livid appearance; no rigor mortis; no fœtid odor; no signs of decomposition. *Brain:* Sinuses filled with very dark blood containing enormous quantity of micrococci. (It was taken by sealed glass tubes before opening of vessel.) All the blood vessels of the brain and its membranes congested; other changes were not notable by naked eye nor by microscope. There was some increase of fluid in the lateral ventricles. The medulla oblongata and a small portion of the cord which was removed through the occipital foramen did not show any morbid changes. *Neck:* Lymphatic and salivary glands enlarged and highly congested. All the large veins highly distended. Blood similar to that found in sinuses of brain. *Tongue* removed from below, intact with the *tonsils*, *pharynx*, *larynx*, and *trachea*. The mucous membrane of all these parts was covered with moderate-sized patches of pseudo-membrane which, in some places, appeared raised over the surface, in others, showing shallow necrotic ulcerations. The same was observed upon the vocal cords and the nasal mucous membrane. In the trachea the exudation was slight, most marked at the bifurcation, and of darker color than in other parts. *Lungs:* Congested with slight hemorrhagic infarctions in lower lobes; a few of the bronchi contained casts of the exudate. *Heart:* Pericardial fluid increased; heart muscle congested; otherwise normal; right side contained large, white, firm clots extending into pulmonary vessels; in left side only red clotted blood. Mycotic erosions were seen upon endocardium below the pulmonary and the aortic valves. Mediastinal and bronchial glands were enlarged and congested. *Liver* enlarged and extremely congested; gall bladder very much distended with very dark bile. *Spleen* normal size, rather hard in consistency, and showing congestion and hemorrhages. *Stomach* showed a few hemorrhagic erosions, and contained only a few drachms of a dark semi-liquid matter. The intestines, although of dark hue, appeared normal. *Kidneys* enlarged, strongly congested, and presented the appearance of acute parenchymatous nephritis. This was confirmed by microscopic examination, which revealed, also, micrococcus emboli in the blood vessels of these organs. The bone marrow, taken from a rib, as well as the parenchyma of the spleen, was infested by micrococci. Rest of organs normal. The urinary bladder was found empty.

Case II.—Girl, two years old, attacked June 14, and died on the 24th. Her condition had varied much from day to day. The blood was examined daily for micrococci, which were always found, but their numbers seemed in direct proportion to the severity of the constitutional symptoms; when the child was worse the micrococci were very abundant.

Case III.—Boy, seven years old; recovered. The blood was examined on three successive days of the disease and micrococci found.

Case IV.—Girl, three years old. The blood examined on the fifth day of disease was found to contain micrococci.

Case V.—Boy, four years old. Diseased mind. The blood examined the third and fourth days of disease was found to contain a few micrococci.

Case VI.—Girl, four years old; mild form of disease. The blood was not examined until the eighth day of disease, when the child seemed nearly well, and no micrococci were found.

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*A small glass tube closed at one end was drawn to a point hermetically closed whilst hot. The sharp point thrust into the jugular vein was broken off and blood drawn up into the tube.

CASE VII.—Girl, eleven years old, mild form of disease. The blood was examined once and no micrococci found.

CASE VIII.—Boy, five years old; grave form of disease. The blood was examined on the fifth and sixth day, and found to contain micrococci.

CASES IX, X, XI, XII.—Four children, between three and twelve years old, in one family. All had the mild form of disease; the blood of each was examined once and no micrococci found.

CASE XIII.—Girl, four years old; recovering from severe attack and still much affected. The blood contained micrococci.

CASES XIV, XV.—Girl, seven years old; boy, nine years old. Both were convalescing from mild form of disease, and the blood contained no micrococci.

The records of the cases just detailed show that in Series No. 1, out of seven cases in which the blood was examined *during life* for micrococci, in six (Cases II, III, V, VI, VII, VIII) no fungi were found, whilst in one case (*IV*) micrococci were somewhat abundant in the vital fluid. These cases, it must be borne in mind, represent the endemic mild diphtheria as seen in Philadelphia. The Ludington cases representing the severe epidemic form of the disease were fourteen in number. In seven of these (Cases I, II, III, IV, V, VIII, XIII) micrococci were found, and in seven (Cases VI, VII, X, XI, XII, XIV, XV) none were present. The cases in which there were no micrococci were all of them very light, or in the stage of convalescence, and the amount of the fungi present in the malignant cases seemed to be proportionate to the severity of the symptoms, and to steadily progress with the disease in the fatal cases.

The study of these two sets of cases is sufficient to enable us to formulate, as established, the proposition that in *endemic mild diphtheria, micrococci are always present in the part locally diseased* but are *usually not present during life in the blood or in the glandular organs, even in cases which prove fatal; that in malignant epidemic diphtheria micrococci are always present in the part locally diseased, and are also usually, and perhaps always to be found in the blood and tissues of severe cases, but are frequently, if not usually, absent from the blood of mild cases.*

At first thought this proposition would seem to prove that bacteria are not an essential but an accidental phenomenon of diphtheria. We think, however, that this is hardly a warranted deduction. The micrococci are *always* present in the throat, and in the fatal cases of endemic diphtheria noted the death was seemingly produced by the local disease, rather than by the infection of the general system. It will almost certainly be found that where endemic diphtheria kills by affecting the general system, micrococci are to be discovered in the blood. Again, if the bacteria obtain entrance through the throat, it is conceivable that they may enter through the lymphatics, and may exist in the interior of the body to some extent before they find their way into the blood in sufficient numbers to make themselves apparent to the microscopist. Confirmatory of this is the circumstance that in Case III, although no micrococci were found in the blood during life, they were present in the fluid in great numbers thirty hours after death. Under these circumstances it is very important to know whether the lymphatics and the blood-making organs are the primary seats of infection or not. We are unable to present clinical evidence upon this point, but desire to call the attention of investigators to the matter, and may state that in animals we have found the spleen and bone marrow especially attacked by the fungus.

The next question which offers itself is, are micrococci found in the blood in other diseases besides diphtheria; and, if so, are such micrococci distinguishable from those found in diphtheritic patients? On this point we have not facts sufficient to warrant positive conclusions. Micrococci must, however, be considered as very rarely present in human blood, for we have made a large number of examinations of blood taken from persons suffering from various diseases and have only found them in three cases other than diphtheria. These cases are as follows:

### SET NO. 3.

CASE XVI.—A woman in the lying-in wards of Philadelphia Hospital; blood examined twice during life; both times micrococci not to be distinguished from those of diphtheria were found in the blood. The patient died, but no autopsy was allowed.

CASE XVII.—Girl, eighteen years old, in the wards of the Philadelphia Hospital, suffering from scarlet fever with very severe angina, the throat being full of exudation. Blood examined three times, full of micrococci, whose abundance progressively increased, and on the morning of her death the blood was loaded with them.

CASE XVIII.—A male English emigrant, about twenty-one years of age, in the wards of the Philadelphia Hospital, suffering from very pronounced typical scarlet fever, with intense angina. Blood examined a few hours before death full of micrococci, exactly resembling in their form and position those of diphtheria. *Autopsy*, Twelve hours after death revealed an acute parenchymatous nephritis without micrococci emboli and intense congestion of the organs.

If it were established that in various septic diseases micrococci of similar forms are found, this would not show that the micrococci are not the cause of the disease; for on the one hand it may be that the peculiarities of the various affections are due to peculiar local conditions and that the constitutional symptoms, which are always much alike, are the expression of a common septicæmia; and, on the other hand, it is also possible that micrococci, which look alike, are really diverse entities.

On closer examination, however, it will be seen that our studies have failed to show positively that micrococci similar to those of diphtheria are present in other diseases. In our first case it is entirely uncertain as to what disease the woman had. She may have been suffering from a diphtheritic infection of the genital organs; and in the two other cases the patients had throat lesions in no way distinguishable from those of common diphtheria; indeed, no less a pathologist than Professor Wagner asserts that the condition in which they were is a form of diphtheria, and describes it under the name of scarlatinal diphtheritis.

In conclusion, it seems to us that our clinical studies do not *prove* that in diphtheria the micrococci are not the cause of the disease, but simply flourish because the disease produces conditions that favor their growth. All the known facts in regard to the clinical history and pathology of diphtheria are capable of explanation upon the theory of the fungal origin of the disease; but they certainly do not establish the truth of such theory. It is to us evident that the relations of micrococci to diphtheria can only be successfully elucidated by experimental inquiry, and that such inquiry must have two directions; first, a study of the life history of the micrococci; second, an experimental investigation as to their power of producing the disease in the lower animals. In the following chapters are given the results we have reached whilst endeavoring to proceed along both these lines of research.

## CHAPTER III.

### PATHOLOGY OF DIPHTHERIA.

Under this heading we will give the results of our studies of autopsies, the microscopic examination of organs and a detailed account of our culture experiments of bacteria.

### PATHOLOGICAL ANATOMY.

Diphtheria and pseudo-membranous croup are considered totally distinct diseases by the majority of clinicians. Some admit a diphtheritic croup, which is to be distinguished from an inflammatory croup.

The results of experiments (which will be detailed in another chapter) and careful studies of the anatomy of the lesion do not justify the above distinction. It will be shown that the morbid process which gives rise to the respective lesions in the pharynx and in the air passages is the same, and the anatomy of the products identical.

It is easy to demonstrate that the apparent difference in the lesions of diphtheria and pseudo-membranous croup, and in the morphology of the exudates is altogether conditioned by and dependent upon the anatomical peculiarities of the pharynx and respiratory passages; and more so yet by the degree of affection.

The submucous tissue of the pharynx is made up of a loose, highly vascular connective tissue which does not restrict the congestion of the vessels and the extravasation of the corpuscular elements. At the same time, however, the rapidly coagulable exudate only partly reaches the surface of the mucous membrane, the bulk of it being kept below by the heavy layer of stratified epithelium.

The submucous tissue of the trachea, on the other hand, is made up of a dense, elastic tissue and a less vascular tissue, backed by the avascular cartilageuous rings. Hyperæmia and extravasations from the vessels are here limited and only severe inflammation will give rise to exudates which are rapidly expelled to the surface by the dense matrix, and meeting with no resistance on the part of the single-layered epithelial covering, coagulate mostly on the surface. Again, the mucous membrane of the fauces and mouth has a squamous not easily detached epithelium, and consequently membrane connected with or springing from such surface is firmly adherent. The epithelium of the trachea is columnar, ciliated, and detaches with the utmost facility, even in normal conditions of the organ; hence, membrane attached to it separates readily. The membrane of diphtheritic trachitis is always readily detached in the line of the epithelium.

This detachment is, according to Rindfleisch, further facilitated by the excessive secretion of the tracheal glands, the liquid forcing itself between the mucous surface and the pseudo-membrane.

We also observed that the exudation on the trachea, even in the simplest inflammatory croup, is met with not only on top of the epithelium, but also below the latter, precisely as in true diphtheritic angina, only in slighter degree.

Our preparations show that the exudation of the crupous inflammation excited artificially in the trachea (see chapter iv), is not merely superficial, but also extends below the basement membrane, as illustrated in the accompanying cut.

In cases of artificial croup as well as in those observed in man, in which the *submucous* infiltration is prominent, we have seen loss of substance, viz, necrotic ulcerations similar to those occurring in genuine diphtheritic angina.

Another distinguishing point made by authors between the pharyngeal and tracheal lesions in question is the independence of their individual occurrence, it being asserted that, if a real malignant diphtheritic trachitis occurs, it is only by extension from the pharynx downwards into the air passages. It is true that diphtheria usually begins in the fauces, but we have observed in several instances the reverse to have taken place; and in two of our rabbits in which an artificial pseudo-membranous trachitis was induced the disease extended also upwards, producing a secondary most violent pseudo-membranous angina. Finally, as the most important difference between diphtheritic and inflammatory croup and between diphtheria and true croup some authorities insist upon the presence of micrococci in one and their absence in the other affection. In a later chapter we will prove that this assertion is untenable.

The frequent absence of the systemic disturbances in the local affections of the air passages can likewise also be explained by the anatomical peculiarity of the trachea and larynx; the dense unyielding subcutaneous and cartilageous tissues of these parts, their deficiency in blood vessels and imperfect connection with the lymphatic apparatus prevents in a great measure the absorption into the system of the necrotic products, so that either recovery or death from stenosis takes place before a possible systemic infection ensues.

We are not ready yet to report in extenso on the general pathological anatomy of diphtheria in man, as our investigation in this direction is not completed. Owing to paucity of time our attention was mainly taken up by experiments upon animals and the study of the natural history of the contagium. Human as well as comparative pathologo-anatomical studies should be continued and carried out exhaustively. Our opportunities for autopsies in man were limited to two cases of diphtheria, viz, one of each of the sporadic and epedemic forms. The results of these are given in chapter II (see case III, of Set 1, and case I, of Set 2). The lesions in animals are described in the tables of experiments in chapter IV.

We next will enter upon our studies of the bacteria so closely associated with the question of diphtheria.

## MICROCOCCI.

### I.—MORPHOLOGY.

### A.—*Recognition of micrococci.*

Great difficulty is sometimes encountered in distinguishing bacteria from other minute organic and inorganic particles. Certain mycelial threads and vibrios, coagulated fibrin, and protoplasmic and fat molecules often closely resemble micrococci.

As this is a question of importance, we will briefly enumerate the various methods which we have employed and found serviceable in the recognition of micrococci.

In zooglea forms the micrococci can be distinguished at one glance by an experienced eye, as the micrococci of an individual zooglea mass are always uniformly of one size and are always at the same distance from one another, in contradistinction to albuminous and fat molecules, which vary in size and are at varying distances from one another.

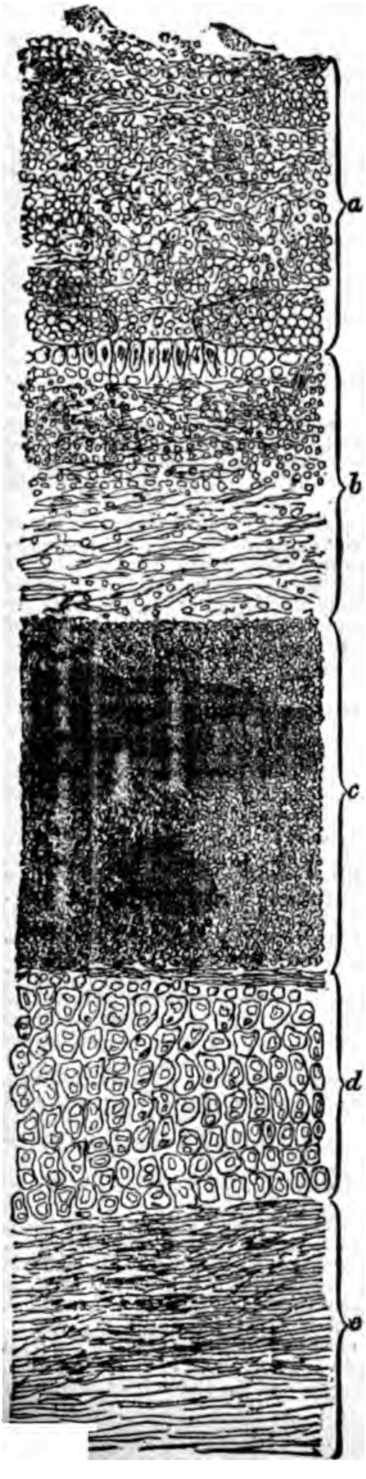
Isolated micrococci may vary in size, as may also the micrococci in the different zooglea groups, some of the latter being made up of smaller and others of larger micrococci.

Micrococci may arrange themselves in pairs and in chains; non-living molecules or granules cannot.

Micrococci are not soluble in strong acids and alkalies, nor in alcohol and ether, as are fat and most other molecules.

Micrococci take the staining well, particularly with hæmotoxylin and aniline dyes, and the aniline dye cannot so easily be washed out as in the case of animal tissues. For this reason sections of tissues may readily be prepared in which only the bacteria are stained. Beautiful preparations may also be made by simply treating sections which a mixture of glycerine and acetic acid; the micrococci in such preparations become yellowish brown and prominent amid the perfectly tranlucent structures.

Tincture of iodine has proved in our hands an excellent staining fluid for bacteria within tissues. If a section has been first treated with a solution of caustic potash, iodine stains the micrococci deep yellow, while the rest of the tissue is only slightly tinged.



*a.* **Superficial** pseudo-membrane. *b.* **Croupous exudate** below basement membrane. Between *a* and *b* **are** seen some remains of surface epithelium. *c.* Ecchymosis **in submucous tissue and infiltration of tracheal** glands with blood corpuscles. *d.* Cartilage. *e.* Outer connecting tissue and muscular investment.

The most important distinguishing point between micrococci on one hand and organic and inorganic particles on the other hand is obtained by culture. Micrococci will always multiply, though sometimes much more rapidly than others. They elongate, divide, form chains or zooglaea masses if brought into a suitbale culture medium.

If the above-mentioned distinctive points are observed, mistakes in recognizing micrococci and other bacteria are entirely out of the question.

In regard to the question of magnifying powers used in recognition of micrococci we can affirm (contrary to statements of some other investigators) that a good one fifth objective is sufficient for the detection of the diphtheritic micrococci, particularly when appropriate staining is used. We have seen no micrococci with a magnifying power of 1,500 which we could not detect with an amplification of 500 diameters. For the finer morphological details of micrococci a high magnifying power is required, and we have habitually used a one-twelfth Zeiss Homog-Immerson.

We desire also here to state that as the result of much experience we are positive that the excessive precautions often insisted upon by authors as necessary in looking for micrococci in the blood, &c., are not in fact necessary. Micrococci do not exist in the air to any extent, and exposure of blood slides for a few minutes in the air never is followed by the appearance of micrococci, when none have previously existed. This is not true of moving bacteria, which in their early growth we ourselves have in some of our former researches mistaken for micrococci, and which may appear rapidly in exposed blood. In order, however, to disarm criticism we have, in all our blood examinations, used the utmost precautions.

### B.—*Morphology of the micrococci as observed in cases of epidemic diphtheria, in the local cases of sporadic diphtheria, and in induced diphtheria in animals.*

When a diphtheritic false membrane was examined (by teasing it in glycerine or fresh aqueous humor) under the microscope immediately after its removal from the pharynx, or the air passages, there was seen, besides the cellular constituents, only one kind of bacteria, viz, micrococci.

Diphtheritic membrane removed some hours previous to examination or removed post mortem, in addition to micrococci, yielded other forms of bacteria described by authorities. Unless the diphtheritic alteration becomes of gangrenous character, we are not able to detect any other bacteria than micrococci. Eberth, who describes only rod bacteria in diphtheria, or those investigators who describe different varieties and mycelium of bacteria, probably examined only membranes removed some time previously, or such as were removed post mortem.

Our experience with a large number of cases is so absolute that we believe the occurrence of rod bacteria is proof that a membrane has begun to putrefy. It may be that in endemic or mild diphtheria the micrococci have not the power of growth that they have in malignant diphtheria, and that consequently rod bacteria have a better chance to develop than in the membrane of the malignant disease.

The micrococci were in every case of at least two sizes, according to their stage of development, or to earlier or later generation (see culture accounts). The smaller ones mostly infested leucocytes and mucous corpuscles within which they were seen dancing in a trembling motion (the appearance has been well compared with flies caught in a fly-trap). The larger micrococci were nearly all in zooglaea form, or *infesting and apparently destroying* the epithelial cells. The latter fact is *not* in accordance with the observation of Klebs and Eppinger, who assert that the mocrococci in diphtheria never infest the epithelium, but merely penetrate between the cells.

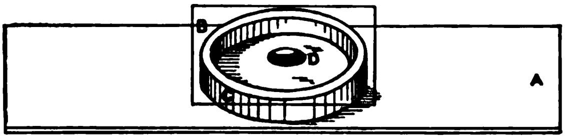
In the blood of patients suffering from the epidemic diphtheria at Ludington, we always found micrococci within the white blood corpuscles (never the red ones), or in zooglea form, or to same extent free, just as they exist in the membrane. Notably the quantity of micrococci was always in direct proportion to the intensity and the stage of the disease, as recorded in the clinical part of this memoir.

### C.—*Methods and objects of culture.*

We have employed two distinct methods of culture. The first is that described by Dr. E. Klein, of London, in his report on infectious pneumo-enteritis, from whose paper the following cut is abstracted:

Fig. I represents, of natural size, one of the culture cells.

A is the object-glass; B is the covering-glass, fixed by means of a thin layer of oil upon the upper (polished) surface of the glass ring C, which is cemented on the object-glass. The covering-glass, which should be as thin as is obtainable, has on its lower surface the droplet D, in which the fungus has been planted. In using this method the minutest speck of the infected material is removed with the point of a clean (previously heated) needle, and placed in a drop of fresh aqueous humor of the eye of a healthy rabbit, or some thoroughly sterilized culture fluid, on a thin square glass-slip. This is inverted and fixed, drop downwards, by means of a thin layer of pure sweet-oil on the glass ring specimens.



The preparation thus mounted was placed in the incubator or oven, where the temperature was automatically maintained at various points, not below 32° and not above 45° C. In most cases we used a temperature of 37° C.

After twenty-four hours the specimen, which we will call the first generation, is used to establish a second generation in a new drop of culture fluid in the following manner: The covering-glass of the above "cell-specimen" is lifted up and, with the aid of a fine capillary tube, a minutest quantity is removed from the edge of the droplet. In the accompanying Figure II this capillary tube is portrayed in its natural size; the contents of the tube between *a* and *b* represent about the quantity that is removed from the drop D of the previous specimen. The capillary tube is then filled with culture fluid up to about the mark *c*. A new clean covering-glass is taken; on its center is deposited a droplet of fluid from our capillary tube, and the covering-glass is then inverted and fixed with a thin layer of oil on the glass ring of another "cell." This new preparation, which represents the second generation, is also placed in the incubator and kept there at the above-named temperature for twenty-four hours. After this time it is used to inoculate another "cell-specimen," representing the third generation, and so on, from generation to generation, until the end of the culture.

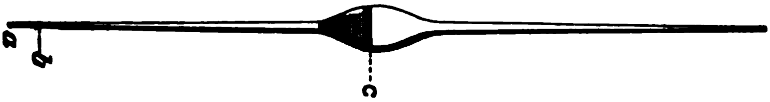


FIG. II.

The second method employed was that perfected by Dr. Sternberg, which we believe has been already described by him in the publications of the National Board of Health. This plan has the advantage over the method of Klein that the cultures can be made on a larger scale for the purpose of inoculation of animals, but we have found the cell and glass cover more useful in observing the growth and development of the fungus.

The following objects were put in cultivation:

Sporadic diphtheritic pseudo-membrane, fresh and dried.
Epidemic diphtheritic pseudo-membrane, dried only.
Fragments of spleen and kidney from epidemic diphtheria, dried.
Pseudo-membrane from artificial croup, produced by ammonia.
Blood from diphtheria.
Blood from septicæmia.
Blood from scarlatina.
Gangrenous matter from foot.

The most extensive and satisfactory cultivations were made with dried diphtheritic matter. The culture experiments with fresh Ludington material were imperfect, as it was impossible for us to carry them on systematically in that town. Perfectly satisfactory results can be expected only when cultures are made in localities where epidemic diphtheria ravages, and the material can be put into culture perfectly fresh.

As a medium for the culture of the diphtheritic fungi the following fluids were used with the best results: bouillon of chicken or rabbit, perfectly sterilized by protracted boiling; ascitic fluid whenever there was opportunity to put it in sealed tubes immediately after tapping; aqueous humor, which is drawn from living animals by a little sharp-pointed pipette, as represented in Figure II, with great facility. Other culture mediums, such as solution of gelatine, egg albumen, Pasteur's fluid, solution of dextrine, and simple sirup were also tried, but with less satisfactory results.

As control experiments the culture fluids were usually tested by placing sealed cells in the incubator for twenty-four hours, but no organisms developed in successful cells or tubes.

### D.—BIOLOGY OF THE DIPHTHERITIC MICROCOCCI AS OBSERVED IN CULTURE.

If a minute particle of fresh diphtheritic matter or some scraping from tongue be put into a drop of pure culture fluid in a cell fixed in a manner as described, there are seen under the microscope a few epithelial scales infested by micrococci averaging in size $\frac{1}{25000}$, but sometimes reaching a maximum of $\frac{1}{14000}$ of an inch, and a few leucocytes filled with minute micrococci, which on account of their extremely small size and their trembling motion within the cell cannot be measured; the surrounding liquid is clear, and will remain so for from six to twelve hours if kept in a cold room; but after having been placed for one single hour in the incubator at a temperature of 40° C., slight clouds appear around the particles in the droplet.

Observed under the microscope and watched for a few hours, the micrococci are seen to undergo the following changes:

The micrococci contained in the leucocyte after a period of slight but very active movement, during which they look as if they were eating up their foster nurse, pass into a quiet state. They now completely fill the corpuscle, which appears to burst, and the whole internal mass escapes as an irregular glass-like body full of quiet uniform micrococci of about $\frac{1}{30000}$ of an inch in diameter, the whole constituting the so-called "zooglaea masses." Often the collapsed vesicle was seen lying alongside of such a mass just escaped from it.

The finer micrococci and those infesting the epithelial cells have grown larger and acquired a yellowish-green color. Some of them can always be seen to be undergoing the process of division, which is better studied, however, a little later.

After twenty-four hours the zooglae masses can be seen to be breaking up and setting free small individual micrococci. The larger micrococci have in the meanwhile elongated; some of them resemble in appearance short rod bacteria, whilst others of them are constricted in the middle like the figure 8. The latter forms have a peculiar trembling motion as if they were making an effort to separate the two parts. Except in the case of the peculiar vibration already noted inside of the leucocytes and this trembling before division, we have found the micrococci always motionless.

The aureole of mucous substance surrounding the isolated micrococci, particularly well described by Pasteur and Sternberg, is well marked at this stage. In color the larger micrococci are somewhat greenish-yellow, while the smaller ones are colorless.

After the lapse of forty-eight hours multiplication is seen to have continued, and to be occurring in micrococci originally derived from the balls. A large number of micrococci are observed elongated or in pairs, and also a few are arranged in fours so as to resemble a sarcina, and in chains. After this no further multiplication will occur, unless new culture pabulum is added. In a second generation the multiplication will proceed in a very vigorous manner so that within twenty-four to forty-eight hours a fresh droplet of culture fluid to which only a few micrococci have been added on a pin is completely filled out with millions of mostly round micrococci. The different forms of grouping are best expressed on the second and third day of culture. Vigorous multiplication continues also in the third and fourth generation and occasionally in the fifth, but in later generations up to the eighth the rapidity of multiplication gradually subsides and is hardly perceptible in a ninth or tenth generation. It is said by some authorities that micrococci kept for a while in a culture tube will diminish in quantity and even disappear; we cannot affirm this from our own experiments. Micrococci may cease to multiply, but in many instances a diminution in quantity had not been perceptible even after the lapse of months.

The above history refers to micrococci from true malignant diphtheria; in the case of cultures of tongue-scrapings the micrococci ceased to multiply as early as the third generation, and frequently in the second generation their growth was very slow. In addition, in tongue-scraping, some leptothrix threads frequently accompanied the micrococci in the first and second culture, and, as well as in diphtheritic culture, bacterium termo made occasionally its appearance in early generations, but *it promptly disappeared if the temperature in the incubator went for a while to* 40° and did not afterwards sink below 35°. Later generations in successful cultivation remained always clean in well-regulated temperatures and never showed any kind of mycelial fungi. Cultures with sporadic Philadelphia diphtheria gave results very similar to those achieved with tongue-scrapings; the micrococci possessed some, but not very much more vitality or proliferating power, their growth usually ceasing in the fourth generation.

In regard to temperature we can affirm from our own culture experiments the following interesting facts with special reference to diphtheritic micrococci.

The micrococci multiply best at from 37° to 40° C.; higher temperatures up to 70° C. do not destroy them but only partly arrest their multiplication, which returns, however, if the 70° is again reduced to 40° or 35°.

Fungi other than micrococci, if met with as an admixture in our culture, perished at a temperature above 50°, and proliferated well only at 30° C. and below. Too low temperature frequently spoiled our cultures, for if any spores of rod bacteria were present they usually developed and displaced the micrococci. In high temperatures, however, the micrococci are stronger and displace easily the several kinds of bacteria we observed in impure cultures.

The diphtheritic micrococci do not seem to need a large supply of oxygen for their growth; they even appear to multiply better when distant from surfaces in contradistinction from the bacteria of putrefaction.

In culture tubes the diphtheritic micrococci are always seen as a precipitate. If there is any mycoderma at the surface it is always a sign that the culture is impure, as the bacteria found on the upper surface are always rod bacteria and bacilli, with very few micrococci. This property renders them especially fitted to flourish in dense membrane and in deep tissue where the supply of oxygen must be very small.

In the following tables are given, in sufficient detail, the several series of cultivations which we have made.

## II.—CULTURE EXPERIMENTS.

### FIRST SERIES.

*Diphtheritic false membrane from the cases of Dr. H. Allport, Philipsburg, Pa., probably malignant diphtheria.*—Twenty cultures were made, being carried on only to third generation. The course and the results of the individual cultures, with the exception of a few failures, were so uniform that the whole series may be recorded in one table.

*Culture experiment, representing No.* 1 *to* 20.

MICROCOCCI.—[Matter used: fresh diphtheritic pseudo-membrane. Case of Dr. Allport.]

| Date. | No. of generations. | Culture fluid. | Mode of culture. | Temperature in incubator. | Mycoderma or precipitate in tube. | Size of. | Quantity and rate of multiplication. | Mode of grouping. | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | Isolated. | In pairs. | Sarcina form. | Torula chains. | Zooglaea. |
| During Apr. and May, 1881. | First | Aqueous humour of rabbit. | Cells | 35° to 40° C. | | $\frac{1}{30000}$ to $\frac{1}{15000}$ of an inch | At first slow then rapid | Many. | Few. | Few. | Few. | Many. |
| | Second | do | do | do | | do | Rapid | do | Many. | do | do | Do. |
| | Third | do | do | do | | do | Very rapid | do | do | do | Many. | Do. |

Many micrococci were in large clouds without any special form of grouping.

All the cultures of this series yielded crops of pure micrococci. No other bacteria interfered in successful tubes. Mycelial fungi were never observed.

### SECOND SERIES.

*Endemic diphtheritic matter obtained from time to time in Philadelphia.*—Twenty-five cultures were made and all the mentioned culture fluids were tried in this series up to a fourth generation. The comparative values of the culture fluids were referred to before.

The general results of the culture experiment were similar to those of the first series up to the second generation. In the third generation the micrococci already began to fail in growth and multiplication, and the fourth generation yielded a still poorer crop. The cultures were occasionally impure—the rod bacteria supervened.

The regulation of the temperature was sometimes defective during the experimentation with this series on account of imperfect working of the mechanism of the incubator. Sometimes the temperature fell down to 20° during the night, and it was frequently observed that rod bacteria made promptly their appearance in large numbers during such intervals and spoiled the cultures. The same occurred with clean cultures when heat was suspended purposely for several days. Those culture tubes, however, which were subjected to a uniform temperature of not below 37° C. did not show any invasion of rod bacteria, and the growth of micrococci continued in the manner described.

The careful measurement of the micrococci in this series, which was best accomplished by measuring the chains of micrococci, revealed a size of $\frac{1}{14000}$ to $\frac{1}{42002}$ of an inch in diameter, the latter size relating more to micrococci in zooglea form. The torula chains were usually made up of the smallest micrococci, approaching in this respect to those of the micrococci balls which we have proven to be formed by the invasion of leucocytes by micrococci.

### THIRD SERIES.

Thirty cultures were made with matter other than diphtheritic, being carried on to the fourth generation. Although the matter used was of the most diverse character, such as ammonia croup (croupous exudation produced in a trachea of a rabbit by ammonia), slough from gangrene of foot, from septicæmia and scarlatina, yet the results in culture were nearly all identical.

One and the same thing gave at one time an excellent crop of micrococci if temperature of the incubator was kept up high enough and pains were taken to keep the culture pure; at another time, and with the same culture fluid, the same tube showed only a few micrococci, but rod bacteria in abundance. This could be nearly always traced to low and irregular temperature of the incubator. In some cases, after the replacing of the micrococci by rod bacteria, the tubes were subjected to a high temperature for several days, when the bacteria disappeared while the micrococci did not reappear, so that the liquid was left clear. But even in successful cultures the growth and multiplication of micrococci were observed to be prosperous only to the second or very rarely to the third generation. In later generation the fungi grew scantily.

In size, shape, and color, as well as in the mode of grouping, the micrococci were the same as those from the diphtheritic pseudo-membrane. If this was not the case in one generation it invariably was so in the next.

### FOURTH SERIES.

Twenty-five cultures were made with epidemic diphtheritic matter from Ludington, and were carried on to the fifth generation. The results were identical in every one of the successful cultures, and the record of one experiment holds good for all the rest.

Neither rod bacteria nor mycelium could be detected at any time of culture. One of the culture-tubes did not show any change in appearance when examined two months later, it having been kept during the whole time in the incubator.

*Culture experiment, representing No.* 76 *to* 100.

MICROCOCCI.—[Matter used: dried diphtheritic membrane. Case of Dr. Shorts, Ludington.]

| Date. | No. of generation. | Culture fluid. | Mode of culture. | Temperature in incubator. | Mycoderma or precipitate in tube. | Size of— | Quantity and rate of multiplication. | Mode of grouping. | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | Isolated. | In pairs. | Sarcina form. | Torula chains. | Zooglaea. |
| During July, 1881. | First | Bouillon or ascitic fluid. | Cell and tube. | 37° C | Precipitate | $\frac{1}{35000}$ to $\frac{1}{14000}$ | Slow; twelve hours later slow but marked. | Few | None | None | None | Moderate quantity. |
| | Second, next day. | do | do | 39 | do | do | Faster; ten hours later; rapid. | Many | Many | Some | None | Large quantity. |
| | Third, third day. | do | do | 38 | do | do | Rapid | Large quantity in all forms of grouping. | | | | |
| | Fourth day | do | do | 40 | do | do | Enormous | Cell specimen is so crowded that mode of grouping is indistinguishable. | | | | |
| | Fourth, fifth day. | do | do | 39 | do | do | Rapid | In all forms. | | | | |
| | Fifth, seventh day. | do | do | 38 | do | do | Slower | In all forms mostly torula chains and zeoglaea forms of yellowish color. | | | | |

### FIFTH SERIES.

Forty cultures were made with epidemic diphtheritic false membrane received from Ludington per express, and were carried to the 10th generation. The membrane was in a semi-dry condition and showed under the microscope the following morphological elements: Epithelial scales and leucocytes both infested by clouds of micrococci. The micrococci were of two sizes, larger ones of a greenish color measuring about $\frac{1}{14000}$ of an inch in diameter, and smaller ones not exceeding $\frac{1}{30000}$ of an inch. There were also seen some rod bacteria and bacilli, and also a number of bundles of mycelial threads resembling leptothrix, of greenish color, united together at one end but separated at the other. These extraneous organisms disappeared, however, in proper culture.

Particular pains was taken to have always a uniform temperature in the incubator and not exceeding 37° C. The results obtained were nearly identical with those in the fourth series. Only these cultures were conducted up to the 10th generation. and a larger proportion of impure culture were encountered here, mostly dependent upon thermal conditions. The record of one of the many uniform and successful culture experiments reads as follows:

*Culture experiment, representing No.* 101 *to* 140.

MICROCOCCI.—[Matter used: diphtheritic membrane removed five days previous by Dr. Shorts, of Ludington.]

| Date. | | No. of generation. | Culture fluid. | Mode of culture. | Temperature in incubator. | Mycoderma or precipitate in tube. | Size of. | Quantity and rate of multiplication. | Isolated. | Mode of grouping. | | | | Rod-bact. | Bacilli. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | In parts. | Sarcina form. | Torula chains. | Zoogloea. | | |
| July | 23 | First | Bouillon of rabbit. | Cells and tubes. | 45° C (with the object to kill the extraneous fungi.) | Precipitate | $\frac{1}{25000}$ to $\frac{1}{12000}$ | Slight | Many | A few | None | None | Some | A few. | |
| | 24 | Second | do | do | 37 | do | do | Rapid | do | Many | Some | do | Large quantity. | None. | |
| | 25 | Third | do | do | 37 | do | do | Enormous | do | do | do | do | do | Do. | |
| | 26 | Fourth | do | do | 37 | do | do | Rapid | do | do | do | Many. | do | | |
| | 28 | Fifth | do | do | 37 | do | do | Slower | do | do | do | do | do | | |
| | 29 | Sixth | do | do | 37 | do | do | Slow | do | do | do | do | do | | |
| | 31 | Seventh | do | do | 37 | do | do | Slow | Only isolated and in torula form | | | | | | |
| Aug. | 2 | Eighth | do | do | 37 | do | do | Very slow | do | | | | | | |
| | 4 | Ninth | do | do | 37 | do | do | Hardly perceptible, or not all. | do | | | | | | |
| | 7 | Tenth | do | do | 37 | do | do | do | do | | | | | | |

Neither mycelium nor rod-bacteria were observed in successful cultures, except in the early (first and second) generation.

NOTE.—Animals were inoculated with third and fifth generation of these cultures, without success.

### SIXTH SERIES.

*Cultivation of tongue-scraping.*—To test the behavior of the micrococci from the mucous membrane of the tongue in cultures, five experiments were made and carried to the fourth generation. In every experiment a result was obtained that the proliferating power of these micrococci was very weak in comparison with those of the diphtheritic exudate. Only in the second generation they multiplied rapidly and precisely in the same manner as the diphtheritic micrococci, and in this generation they are morphologically perfectly identical with them.

### SEVENTH SERIES.

Five cultures were made with epidemic diphtheritic matter which had been for two months exposed to air and light, frequently to the direct rays of the sun. The results of the culture were surprising, as it was found that the micrococci of this dried membrane had lost a great deal in their proliferating power. In the second generation a moderate crop of micrococci were obtained, whilst in the third generation very slow or hardly any multiplying property could be observed.

This shows distinctly that the same diphtheritic micrococci which in the fourth series of cultures had a vigorous power of growth and multiplication had lost greatly these properties (simultaneously with the loss of virulence upon animals).

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## CHAPTER IV.

## THE NATURE OF DIPHTHERIA.

The experiments which we have made upon the lower animals with diphtheritic materials have been in two sets.

First. Those with membrane taken from cases of the endemic diphtheria of Philadelphia.

Second. Those made with materials obtained from the epidemic diphtheria of Ludington.

## SECTION A.—ENDEMIC DIPHTHERIA.

*First series of experiments.—Inoculation of diphtheritic matter subcutaneously or in the mucous membrane of mouth.*

| Number of experiment. | Date of inoculation. | Animal. | Inoculation. | Recovery or death. | Result of post-mortem, and of microscopic examination. | Remarks chiefly upon source of matter employed. |
|---|---|---|---|---|---|---|
| 1 | Apr. 22 | Small rabbit, No. 1 | Inoculated on tongue with fresh diphtheritic membrane. | Remained perfectly well to May 16, 24 days, when they were accidentally killed. | No signs of diphtheritic inflammation anywhere. The spleen, lymph. glands, liver, and lung showed some tubercle granulations. The rest of the organs normal. No bacteria in the organs. | Case I.—Material taken by Dr. Cardeza from child, 3 hours previously to inoculation. Child's throat had been touched with tincture of iron and glycerine previously. |
| 2 | 1880.<br>Apr. 22 | Small rabbit, No. 2 | Same as last.............. | | | |
| 3 | Apr. 24 | Small rabbit, No. 3 | Same as last ............... | Remained well.................. | ........................................ | Same case. The throat for 24 hours previous to the removal had not been touched by anything. |
| 4 | Apr. 24 | Small rabbit, No. 4 | Same as last ............... | Died May 10...................... | No lesions except lymphatic glands swollen and tuberculous; also spleen. No bacteria in organs. | Same case and exudation as last. |
| 5 | Apr. 24 | Large gray rabbit, No. 5. | Inoculated in mouth; had also a piece of membrane put under the skin of the side. | May 4, was feverish for several days; a hard lump developed on the side at the seat of inoculation consisting of cheesy matter. June 6, animal well, cheesy lump smaller but persistent. Animal remained well. | Cheesy matter composed of pus, compound granule cells, debris, and numerous bacteria. | Same case. The child recovered from the acute attack, which was followed by paralysis, finally resulting in death. |
| 6 | Apr. 29 | Small albino rabbit, No. 6. | Inoculated with fresh diphtheritic membrane in mouth, tongue, roof, and pharynx, and also subcutaneously on thigh. | Died May 2, 70 hours after inoculation, in convulsions, which commenced 6 hours previous to death. | Small cheesy lump at the seat of subcutaneous inoculation. Tongue ulcerated; no signs of diphtheritic inflammation anywhere: all organs hyperæmic, otherwise of normal appearance, but upon microscopic examination tubercular granulations well marked in lung, liver, spleen, and lymphatic glands. No bacteria in organs, except lungs, where are also hemorrhage infarctions. | Case II.—Removed by Dr. Dunmire from the throat of child a few hours previously. |
| 7 | Apr. 29 | Small albino rabbit, No. 7. | Same as last ................ | Animal remained well ........... | ........................................ | Same case. |

| | | | | | | |
|---|---|---|---|---|---|---|
| 8 | Apr. 29 | Small rabbit, No. 8 | Same as last | Remained well to May 1st, when killed accidentally. | Post-mortem revealed no lesions | Case III.—From Dr. Cardoza; inoculation made 15 minutes after removal of the membrane from the child's throat. This case was in same family as No. 1, and originated apparently in contagions. |
| 9 | Apr. 29 | Small rabbit, No. 9 | Same as last | Remained well to May 16, when accidentally killed. | | |
| 10 | Apr. 29 | Albino rabbit, middle sized, No. 10. | Same as last | Remained well | | |
| 11 | Apr. 30 | Rabbit, No. 3 | Reinoculated with diphtheritic matter in mouth and subcutaneously. May 7, inoculated third time. | Remained well up to May 13; found dead May 14. | Small cheesy lump on thigh at the place of inoculation. All organs tubercular, otherwise to the naked eye of normal appearances. No bacteria in organs. | Case IV.—From Dr. James Collins, twelfth day of disease. Matter semi-liquid, mixed with blood. The case afterward died. |
| 12 | Apr. 30 | Dog, No. 1 | Inoculated with diptheritic membrane in mouth and thigh. | Remained well. | | Same case. |
| 13 | Apr. 30 | Large cat, No. 1 | Inoculated with diphtheritic matter in mouth and subcutaneously on right thigh. | Remained well; a large lump developed in skin at seat of inoculation, which eventually disappeared. No micrococci in blood. | | Case IV.—From Dr. Collins. Case recovered. |
| 14 | Apr. 30 | Rabbit, No. 11, large Albino. | Same as last | | | |
| 15 | Apr. 30 | Rabbit, No. 12, large old Albino. | Same as last | Remained well. | | |
| 16 | May 1 | Small rabbit, No. 13. | Same as last | A small cheesy lump developed at seat of inoculation; died May 12. | Slight exudation on the mucous membrane of the larynx and trachea of grayish color, and translucent. Trachea and lungs much congested. All organs tubercular; in the lungs are seen profuse hemorrhagic infarctions, and numerous bacteria. No bacteria in the organs. | Case V.—From Dr. W. S. Stewart. Membrane inoculated fresh on the day of removal. |
| 17 | May 1 | Large cat, No. 2 | Same as former | Remained well; lump developed on side and disappeared within a week, healing perfectly. No micrococci in blood. | | Same case. |
| 18 | May 1 | Small cat, No. 3 | Inoculated in mouth | Remained well | | Same case. |
| 19 | May 1 | Dog, No. 2 | Inoculated in mouth, pharynx, tonsils, tongue, and also subcutaneously on the side, with fresh diphtheritic matter. The latter also given to the animal mixed with food. | Remained well. Killed June 11. | Cheesy lump which had existed for a long while on the side found to have been absorbed; in its place found a hard lump, probably of cicatricial tissue. No lesions perceptible. Blood examined during life did not show any bacteria. | |
| 20 | May 4 | Small cat, No. 4 | Inoculated with dried diphtheritic matter in mouth and subcutaneously. | Remained well. Killed June 12. | No lesions found; blood did not contain bacteria. | Case VI.—From Dr. Frank R. Brunner. Membrane removed several days previously from woman of 45 years; apparently much decomposed. |

## SECTION A.—ENDEMIC DIPHTHERIA—Continued.

*First series of experiments.—Inoculation of diphtheritic matter subcutaneously or in the mucous membrane of mouth.*—Continued.

| Number of experiment. | Date of inoculation. | Animal. | Inoculation. | Recovery or death. | Result of post-mortem, and of microscopic examination. | Remarks chiefly upon source of matter employed. |
|---|---|---|---|---|---|---|
| 21 | May 4 | Large rabbit, No. 14. | Same as in last experiment | Remained well. Has large lump at place of skin inoculation. | No lesions except a large cheesy lump on side. No microscopic examination made. | |
| 22 | May 4 | Cat, No. 5 | Same as last | Remained well. Killed June 12 | Large cheesy lump at the place of subcutaneous inoculation; no signs of diphtheritic inflammation; lungs highly congested, the remaining organs all appearing normal to the naked eye; but microscopic examination showed tubercular granulations everywhere; hemorrhagic infarctions in lungs; no bacteria in organs except lungs, | Case VI.—From Dr. Collins. |
| 23 | May 7 | Large rabbit, No. 15. | Same as last | Remained well up to May 19. Found dead May 20. | | |
| 24 | May 7 | Small rabbit, No. 9. | Reinoculated with fresh diphtheritic matter in mouth and subcutaneously. | Killed accidentally | Post mortem revealed no lesion | See experiment 9. |
| 25 | May 7 | Small rabbit, No. 3. | Inoculated the third time as before with fresh matter. | Died May 9 | A small cheesy lump on thigh at the place of inoculation; all organs tubercular, otherwise to the naked eye of normal appearance; no bacteria in organs. | |
| 26 | May 9 | Dog, No. 3 | Inoculated in mouth and skin with fresh membrane. | Remained well | | Case VIII.—From Dr. James Collins. |
| 27 | May 9 | Small cat, No. 6. | Same as the last | Remained well. Killed June 12 | All had cicatrizing lump at place of skin inoculation; no other lesions detected; no bacteria in blood. | From Dr. James Collins. |
| 28 | May 9 | Small cat, No. 7. | | | | |
| 29 | May 9 | Small cat, No. 8. | | | | |
| 30 | May 11 | Goat, No. 1 | Inoculated in mouth and subcutaneously with fresh membrane. | Remained well | | Case IX.—From Dr. H. C. Wood. Taken from a case the second day of the disease, the attack having been derived by contagion from the cases of Dr. Cardesa. |
| 31 | May 11 | Cat, No. 9 | Similar inoculation | Remained well. | | |
| 32 | May 11 | Cat, No. 10 | Same as before | Found dead June 11 | No microscopic examination made. | |

There are recorded in the table just given thirty-two experiments, in only six of which the animals died, unless killed accidentally or otherwise. The time between the dates of death and of the last inoculation was, Experiment 4, six days; Experiment 6, seventy hours; Experiment 11, fifteen days; Experiment 16, eleven days; Experiment 23, thirteen days; Experiment 25, two days. The question naturally arises as to whether the few animals in which the inoculation was followed by death died of diphtheria or of some other disease. Of these fatal cases there were only two in which a strong suspicion of septic poison could fairly be entertained; death was too long delayed. In one of these, Experiment 25, the animal died two days after the third inoculation, but it had been first inoculated 52 days previously, and was very tubercular; so that the last inoculation may have had nothing to do with the fatal result. In Experiment 6 no bacteria were found except in the lungs, no false membrane existed anywhere, the lungs were full of hemorrhagic infarctions and the peculiar long-continued convulsions are not a symptom commonly seen in septic diseases of the rabbits. There is therefore no proof that the rabbit died of diphtheria or of septic poisoning; it is probable that the wound of the larynx brought about the fatal result.

In only one of the fatal cases were there any exudations present in any organ which could give rise to the slightest suspicion that the animal died from diphtheria. In this case, Experiment 16, there was only a catarrhal inflammation of trachea [with an exudation] which presented some of the characteristics of false membrane. In none of these cases were micrococci found in the blood. There is therefore little reason for believing that the rabbits died from diphtheria or even from septic poisoning. Of what, then, did they die?

A study of the post-mortem reports will show that in nearly every case the internal organs were tubercular and in many cases intensely so; also, that tubercular disease was found in the organs of those rabbits which were killed some days after inoculation. It is therefore a very natural belief that in those cases in which death was long delayed it was due to tuberculosis. In order to discover whether the diphtheritic exudation acted specifically in the production of tubercle, or whether it merely set up a local inflammation which formed a focus of infection, we experimented by putting under the skin of rabbits small masses of innocuous foreign matters.

*Second series of experiments.—Inoculation of foreign bodies subcutaneously.*

| Number of experiment. | Date of inoculation. | Animal. | Inoculation. | Recovery or death. | Result of autopsy and microscopic examination. | Remarks. |
|---|---|---|---|---|---|---|
| 33 | Apr. 19 | Small rabbit, No. 16. | A piece of wood, fragment of a match, put below the skin in the posterior part of the neck and the wound closed by a suture. | Wound healed rapidly, but subsequently a small lump of cheesy matter was formed. The animal was feverish for several days. In the lapse of two weeks the lump disappeared, and the animal remained well to date, June 8. | | The foreign bodies used here have been before the experiments thoroughly washed and cleaned. |
| 34 | Apr. 22 | Small albino rabbit, No. 17. | Treated similarly | Wound healed rapidly, but within a few days a large lump formed; ulceration set in, and cheesy matter protruded from wound; animal became emaciated, feverish. Died May 13. | All organs appeared hyperdræmic; liver contains several small abscesses and numerous small nodules, the latter also seen in lung and spleen; lymphatic glands swollen; microscopic examination revealed large collections of tubercle granulations in all organs; the proportion of white blood corpuscle increased; no bacteria in blood. | |
| 35 | Apr. 22 | Small rabbit, No. 18. | A piece of clean glass put below the skin in the right thigh; wound closed. | Result similar to last, only slower. Died May 20. | Lesions similar to the last, but slighter in degree; hemorrhagic infarctions in lungs very marked. | |
| 36 | Apr. 25 | Large albino rabbit, No. 19. | A piece of glass put deep below the skin in the right thigh; wound closed. | Wound healed at first, then severe ulceration set in, cheesy matter protruding from wound; the latter increased to four times the original size. Died May 10. | No decided lesions to the naked eye; microscopic examination showed all organs to be profusely tubercular; hemorrhagic infarctions in the lungs; echinococci cysts in the liver; no bacteria in the organs. | |
| 37 | Apr. 25 | Albino rabbit, No. 20. | Treated similarly | Wound healed after slight suppuration. Animals remain well. | | |
| 38 | Apr. 25 | Small rabbit, No. 21. | Treated similarly with a piece of cork. | | | |
| 39 | Apr. 25 | Small rabbit, No. 22. | Treated similarly with a small bunch of clean hair. | | | |
| 40 | May 6 | Small rabbit, No. 23. | A piece of wood, fragment of a match, put deep below the skin in the right thigh. | Cheesy lump formed rapidly and protruded from wound. Died May 19. | All organs showed masses of tubercle granulations; no other decided lesion; no bacteria in the organs. | |
| 41 | May 6 | Small rabbit, No. 24. | A piece of wire put below the skin in the left thigh. | Cheesy lump formed; the wire ulcerated away. Died May 15. | Hemorrhagic infarctions in lungs; tubercle granulations everywhere, although not very marked; no bacteria in the organs; none in the blood. | |

It will be seen that in five out of nine of these experiments tubercle was found after death; this large proportion apparently demonstrates that a simple local inflammation may in the rabbit act as a source of tubercular infection. Now, when in our first experiments rabbits were inoculated with diphtheritic matter, inflammation was almost always induced at the seat of the lesion, with the formation of large lumps containing cheesy matter. These facts being so, it is a fair deduction that the tubercles were secondary to these inflammatory foci, and were therefore an indirect result of the inoculation.

These experiments, although not perhaps as numerous as they ought to be, seem to warrant the deduction that inoculation with materials taken from patients suffering from the endemic mild diphtheria of Philadelphia frequently produces a secondary or indirect tuberculosis in the rabbit, but very rarely if ever causes any disease in the rabbits comparable to diphtheria in man, or even any septic disorder; of course the experiments do not prove that malignant cases of diphtheria may not occur in Philadelphia and have different relations to inoculation.

The method by which Trendelenburg asserts that he succeeded in producing diphtheria in rabbits consits in placing the exudation matter in the trachea. We naturally have suspected that the membrane when placed in the trachea produces simply a trachitis. This suspicion has been strengthened by the observation that acute pseudo-membranous trachitis and angina occur in rabbits. Such an epidemic destroyed, during the winter of 1879, a number of rabbits kept by one of us in a perfectly clean place. The rabbits first showed sickness by refusing food; examination then detected swelling of the tonsils with exudation. There was a high fever with increase of the local symptoms until the animals became entirely unable to swallow. Death occurred in from three to seven days, preceded by great difficulty of breathing and profound exhaustion. False membrane was abundant in the mouth and trachea, and on examination showed all the characteristics of diphtheritic exudation.

In order to determine whether the tracheal inoculation of rabbits with diphtheritic membrane taken from the mild type of the disease will cause pseudo-membranous trachitis, the following experiments were performed:

*Third series of experiments.—Inoculation with diptheritic matter in the trachea.*

| Number of experiment. | Date of inoculation. | Animal. | Inoculation. | Recovery or death. | Result of autopsy and microscopic examination. | Remarks. |
|---|---|---|---|---|---|---|
| 42 | May 31 | Large albino rabbit, No. 27. Fresh rabbit. | Inoculated with dried diphtheritic matter, mixed with water, in the trachea, from without. | Still alive and well, June 20. |  | Case X.—Of diphtheria, received through Dr. Jaggard, about 24 hours after removal. The membrane dry and hard, apparently in perfect condition. |
| 43 | June 1 | Albino rabbit, No. 10. See experiment 10. | Same as last. | Died June 6, 5 days after inoculation, in convulsions. | External wound had healed perfectly; some ecchymosis noticeable, and the subcutaneous tissue infiltrated and congested. The wound in the trachea did not quite heal; larynx and trachea are congested and covered by a delicate pseudo-membrane, which reaches, near the larynx, a thickness of 1 mm. Microscopically, it appears identical with the natural and with the ammonia false membrane, containing micrococci in large number. No bacteria in blood, none in organs. The organs are tubercular, more especially the liver, where large nodules can be seen, even by the naked eye. No hyperæmia of organs, as in the ammonia specimen. | Same case. |
| 44 | June 14 | Young albino rabbit, No. 37. | Inoculated with dried diphtheritic matter, mixed with water, in the trachea | June 18. Evening. Animals apparently well; take food, &c.; breathing not much interfered with. The same evening killed rabbit 37; No. 38 was found dead June 19. | No lesions; no bacteria in blood, which was very carefully examined. | Case II.—Diphtheritic matter taken by Dr. Richard A. Cleeman from throat of patient untouched; inoculation about 36 hours after membrane was taken; it was dried quickly and was in good condition. |
| 45 | June 14 | Young albino rabbit, No. 38. | Same as last. |  | No lesion; blood not examined. | Same as last. |

These experiments show that the membrane of endemic diphtheria will produce a pseudo membranous trachitus, and the question arises, is the pseudo-membrane proof of a specific trachitis, or is in any trachitis of sufficient intensity accompanied by the formation of a false membrane? To answer this query the following experiments were undertaken.

*Fourth series of experiments.—Injection of ammonia into the trachea.*

| Number of experiment. | Date. | Animal. | Inoculation. | Recovery or death. | Result of autopsy and microscopic examination. | Remarks. |
|---|---|---|---|---|---|---|
| 46 | May 15. 4 p. m. | Large albino rabbit, No. 11. | Injected three or four drops of aqua ammonia into the trachea from without, the trachea being laid bare and a small opening cut into it. | Died May 18, 1 p. m. in convulsions, 69 hours after inoculation. During sickness breathing of the animal was extremely affected, very forced, deep, the rabbit opening the mouth widely at each straining effort, and raising the head; did not take food except the last twelve hours before death, when he seemed to feel easier. | Wound in skin and muscles covering the trachea was suppurating; tracheal wound had healed. All organs strongly hyperæmic, and tubercular nodules recognizable by naked eye. On opening the larnyx and trachea a well-developed pseudo-membrane of 1 to 3 mm. in thickness was seen, which reached below the bifurcation and into the smaller bronchia. It resembles fully in color, consistency, and easiness of detachment, the natural croupous membrane, and is perfectly identical with the latter upon microscopic examination. Micrococci are abundant, both in spheres and disseminated; none in internal organs except the lungs. Tubercles most prominent in the lungs, spleen, and lymphatic glands. Hemorrhagic infarction in lungs. | |
| 47 | May 15, 4 p. m. | Large albino rabbit, No. 12, about 4 years old. | Treated with ammonia similarly to the foregoing. | Died May 18, 4 p. m., 73 hours after inoculation. Animal seemed not to suffer and took food well; death in convulsions, which lasted about 3 hours. | External wound as well as that of the trachea had perfectly healed. Lesions perfectly similar to those of foregoing rabbit, only less intense in degree. Tubercles more scarce; lungs less hyperæmic and less infarcted. No micrococci in blood; pseudo-membrane fully developed and perfectly similar to foregoing. Bacteria and micrococc present in membrane and in lungs, but not in other organs. | |
| 48 | May 28, 12 o'ck. | Albino rabbit, No. 7. | Treated with ammonia like foregoing rabbits, experiments 46 and 47. | Died May 30, 11 a. m., 71 hours after operation. | Lesions fully identical with last rabbit, experiment 47. | |

*Fourth series of experiments.—Injection of ammonia into the trachea.*—Continued.

| Number of experiment. | Date. | Animal. | Inoculation. | Recovery or death. | Result of autopsy and microscopic examination. | Remarks. |
|---|---|---|---|---|---|---|
| 49 | May 28, 12 o'ck. | Cat. No. 7 ........ | Same as last experiments, 46, 47, and 48. | Died May 30, 2 p. m., 50 hours after operation. | Lesions and well-developed false membrane similar to those in the last three rabbits, but here absence of tubercles. No micrococci in blood, and none in organs. | |
| 50 | May 28, 12 o'ck. | Dog, No. 3........ | Same as last ................. | Great difficulty of breathing and inability to swallow followed the operation, but animal was artificially fed with milk, &c.; 12 days after the operation seemed to be recovering; killed June 9. | Body much emaciated; skin wound healed, while tracheal wound was open yet; slight congestion of tissues around trachea. In many places on the mucous membrane of trachea traces as disappearing false membrane seen; whole trachea covered by thick tenacious mucus containing large quantity of leucocytes, some giant cells, and micrococci in moderate quantity. Spleen highly tubercular, tubercles in liver, lymphatic glands, and some in lungs. No bacteria in blood taken from jugular vein immediately after death. | |
| 51 | June 8, 4.30 p.m. | Fresh rabbit, No. 25, about three months old. | Treated with ammonia similarly to foregoing five experiments, 46, 47, 48, 49, 50. | Died June 9, 4 p. m.; no convulsions. | Autopsy made immediately after death. Wound in skin healed; tracheal wound open; the tissues around latter strongly hyperæmic; trachea nearly filled by false membrane. A teased preparation of membrane taken five minutes after death showed the usual elements of a natural diphtheritic membrane with great abundance of micrococci; the blood did not contain micrococci. Lungs much congested; its vesicles largely filled with croupous exudation, blood corpuscles, and micrococci. All other organs normal and not containing bacteria. | |
| 52 | June 8, 4.30 p.m. | Rabbit, No. 26.... | Same as last ................ | Died immediately from operation, too much ammonia having been given. | | |

The experiments which are recorded in the last table show that ammonia is able to produce in the cat and dog as well as in the rabbit a pseudo-membranous trachitis. Professor Oertel states that the membrane produced by the cauterization of the trachea differs from diphtheritic membrane in containing no bacteria. What has led him to such an assertion we cannot comprehend. When the death occurred very quickly bacteria and micrococci may have been less abundant in the traumatic membrane than in that taken from the throat of patients, but when the animal survived some days and the bacteria had sufficient time to develop themselves—when, in other words, they were afforded as good opportunity of growth as in the natural disease—they were immensely abundant, in some cases seeming to make up a large part of the bulk of the membrane. *A priori* we would expect this result, since we have demonstrated that there is no physical difference to be found between the micrococcus of the mouth and the micrococcus of diphtheria. When, then, trachitis, under the influence of the irritant, is set up and exudation poured out, it seems a necessity that the micrococcus shall rapidly spread in the soil thus provided for it. To see whether organic irritants other than diphtheritic exudations will produce a pseudo-membranous trachitis, the following experiments were performed:

*Fifth series of experiments.—Inoculation with foreign bodies, pus, &c., in the trachea.*

| Number of experiment. | Date. | Animal. | Inoculation. | Recovery or death. | Result of autopsy and microscopic examination. | Remarks. |
|---|---|---|---|---|---|---|
| 53 | May 19 | Large rabbit, No. 14. See experiment 21. | Inoculated in the trachea with slough from a bed sore. | Wound healed rapidly, the animal recovering completely. | | |
| 54 | June 3 | Small rabbit, No. 28. Fresh rabbit. | Inoculated in the trachea and in the thigh muscles with exudation from throat of a scarlet fever patient. | Died June 12 | Large cheesy lump on thigh. Some congestion and translucent mucus around tracheal wound which had not healed; no false membrane. No lesions in the organs; not examined for micrococci. | Case X.—From Dr. Fulton, the matter being product of ulceration of a scarletinal sore throat. |
| 55 | June 3 | Small rabbit, No. 29. | Inoculated in the trachea only, with the same matter as last. | Died June 10 | Skin wound healed; upon dissection a cheesy abscess found below subcutaneous tissue, pressing upon the trachea, and probably having been the cause of death. No other lesions perceptible. No micrococci in blood. None in organs. | |
| 56 | June 8 | Small rabbit, No. 30. | Inoculated in trachea with the pseudo membrane produced by ammonia in rabbit No. 25, experiment 49. | Animal well June 18 | | |
| 57 | June 8 | Small rabbit, No. 31. | Same as last | Killed June 16 | No lesion except congestion of trachea and large cheesy lump between the trachea and skin. | |
| 58 | June 8 | Small rabbit, No. 32. | Inoculated in trachea with purulent mucus taken from trachea of dog No. 3, experiment 48. | Died June 11 | No lesions in any organ perceptible; tracheal wound not healed. No bacteria in blood. | |
| 59 | June 9 | Large rabbit, No. 33. | Inoculated with ichorous pus in trachea. | Animal well | | |
| 60 | June 10 | Small rabbit, No. 34. | Inoculated with pus in trachea. | Found dead June 11 | No lesions except congestion of trachea. | |
| 61 | June 10 | Small rabbit, No. 35. | Same as last. | Died June 18 | Large cheesy lump between skin and trachea. Wound in trachea not healed; on opening the trachea a distinct pseudo-membrane of from 1 to 1½ millimeters in thickness was found, prominently seen only below the tracheal wound; *i. e.*, in the lower half of the trachea and the bifurcation. Microscopically, this membrane was identical with the natural diphtheritic | |

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| | | | | | membrane and with those produced by introduction of ammonia, and of diphtheritic matter in the trachea. Micrococci in large quantity all through it. Cheesy abscess was found in the left lung; many air vesicles of both lungs filled with a croupous exudation containing multitudes of bacteria; prominent miliary tubercle in all organs. No fungi in the kidneys; blood not examined. | |
| 62 | June 10 | Small rabbit No. 36. | Inoculated with ichorous puss in trachea, and also deep in muscle. | Died June 17…………………… | Large cheesy lump upon trachea, the latter much congested. Within the trachea a very distinct pseudo-membrane was developed in the lower half of the same macroscopic and microscopic character as that of last experiment. Croupous inflammation of lungs. Other organs normal. | |

*Fifth series of experiments.—Inoculation with foreign bodies, pus, &c., in the trachea.*

| Number of experiment. | Date. | Animal. | Inoculation. | Recovery or death. | Result of autopsy and microscopic examination. | Remarks. |
|---|---|---|---|---|---|---|
| 53 | May 19 | Large rabbit, No. 14. See experiment 21. | Inoculated in the trachea with slough from a bed sore. | Wound healed rapidly, the animal recovering completely. | | |
| 54 | June 3 | Small rabbit, No. 28. Fresh rabbit. | Inoculated in the trachea and in the thigh muscles with exudation from throat of a scarlet fever patient. | Died June 12 | Large cheesy lump on thigh. Some congestion and translucent mucus around tracheal wound which had not healed; no false membrane. No lesions in the organs; not examined for micrococci. | Case X.—From Dr. Fulton, the matter being product of ulceration of a scarlatinal sore throat. |
| 55 | June 3 | Small rabbit, No. 29. | Inoculated in the trachea only, with the same matter as last. | Died June 10 | Skin wound healed; upon dissection a cheesy abscess found below subcutaneous tissue, pressing upon the trachea, and probably having been the cause of death. No other lesions perceptible. No micrococci in blood. None in organs. | |
| 56 | June 8 | Small rabbit, No. 30. | Inoculated in trachea with the pseudo membrane produced by ammonia in rabbit No. 25, experiment 49. | Animal well June 18 | | |
| 57 | June 8 | Small rabbit, No. 31. | Same as last | Killed June 16 | No lesion except congestion of trachea and large cheesy lump between the trachea and skin. | |
| 58 | June 8 | Small rabbit, No. 32. | Inoculated in trachea with purulent mucus taken from trachea of dog No. 3, experiment 48. | Died June 11 | No lesions in any organ perceptible; tracheal wound not healed. No bacteria in blood. | |
| 59 | June 9 | Large rabbit, No. 33. | Inoculated with ichorous pus in trachea. | Animal well | | |
| 60 | June 10 | Small rabbit, No. 34. | Inoculated with pus in trachea. | Found dead June 11 | No lesions except congestion of trachea. | |
| 61 | June 10 | Small rabbit, No. 35. | Same as last. | Died June 18 | Large cheesy lump between skin and trachea. Wound in trachea not healed; on opening the trachea a distinct pseudo-membrane of from 1 to 1½ millimeters in thickness was found, prominently seen only below the tracheal wound; *i. e.*, in the lower half of the trachea and the bifurcation. Microscopically, this membrane was identical with the natural diphtheritic | |

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| | | | | | membrane and with those produced by introduction of ammonia, and of diphtheritic matter in the trachea. Micrococci in large quantity all through it. Cheesy abscess was found in the left lung; many air vesicles of both lungs filled with a croupous exudation containing multitudes of bacteria; prominent miliary tubercle in all organs. No fungi in the kidneys; blood not examined. |
| 62 | June 10 | Small rabbit No. 36. | Inoculated with ichorous puss in trachea, and also deep in muscle. | Died June 17 | Large cheesy lump upon trachea, the latter much congested. Within the trachea a very distinct pseudo-membrane was developed in the lower half of the same macroscopic and microscopic character as that of last experiment. Croupous inflammation of lungs. Other organs normal. |

In looking over the last table, it will be seen that in two of the ten experiments pseudo-membranous trachitis was caused by the introduction of organic matter into the trachea. In both of the cases in which false membrane was produced the injected material was pus; and it will be noticed that only four such experiments were made, so that the proportion of successful result is very large; larger, indeed, than with true diphtheritic exudation in our experiments.

Trendelenburgh found that not only ammonia but also various other chemical irritants are capable of causing the formation of false membrane in the trachea. Many years since it was proven that tincture of cantharides will do the same thing. It would seem, therefore, that in the trachea the formation of a pseudo-membrane is not the result of any peculiar or specific process, but simply of an intense inflammation which may be produced by any irritant of sufficient power. The experiments so far detailed seem to establish the following propositions:

First. *That it is difficult to produce in the rabbit a rapid septic disorder with the matter taken from ordinary cases of so-called diphtheria as we see them in Philadelphia.*

Second. *That tracheal inoculations with this matter will sometimes cause a pseudo-membranous trachitis.*

Third. *That both septic animal matter and non-organic irritants placed in the trachea cause pseudo-membranous trachitis which we have failed to distinguish from diphtheritic trachitis, the membrane in both cases containing micrococci.*

Fourth. *The occurrence of a false membrane in the trachea is the result not of the specific character but of the intensity of the inflammation.*

## SECTION B.

### EPIDEMIC DIPHTHERIA.

After studying the subject of endemic diphtheria, we next made trial of material from Ludington, and with very different results.

*Sixth series of experiments.—Inoculation with epidemic diphtheritic matter from Ludington.*

| Number of experiment. | Date. | Animal. | Inoculation. | Result. | Autopsy and microscopic examination. |
|---|---|---|---|---|---|
| 63 | 1881.<br>June 23 | Rabbit............ | In trachea with matter (from Roche case), material three days old. | Died June 26.......... | Autopsy one hour after death. A huge diphtheritic ulceration occupying whole front of neck. Trachea full of exudation, which extends to the pharynx, tonsils, roof of mouth, and back of tongue; exudation not very tough, full of micrococci, bone marrow (examined fresh) filled with micrococci.<br>Microscopic examination of organs showed—lung croupous pneumonia; liver and kidneys, cloudy swelling, with hemorrhagic infarctions, and only a few of the arterioles and capillaries blocked upwith micrococci masses; spleen normal, and not containing micrococci. |
| 64 | June 23 | Rabbit............ | Same as last ............... | Died June 27.......... | Two hours before death, blood taken in tubes from the jugular coagulated instantly, and contained an enormous amount of micrococci.<br>Autopsy immediate; at place of wound around trachea, a large ulceration filled with exudation, which was composed of leucocytes fibrin and micrococci; mucous membrane of trachea inflamed; larynx filled with pseudo-membrane. The latter contained abundantly micrococci. Lungs, croupous pneumonia; rest of organs normal, and no micrococcus emboli after very careful examination. |
| 65 | June 23 | Rabbit............ | Same as last ............... | Died June 28 ......... | Blood examined after death full of micrococci; a large sloughing diphtheritic ulcer at seat of inoculation, with much exudation composed largely of micrococci, but containing numerous rod-bacteria also; trachea inflamed, containing very little exudation. Double croupous pneumonia; also empyæma. Rest of organs normal. No micrococci could be discovered in any of the organs except in the air-vesicles of lung. |
| 66 | June 23 | Rabbit............ | In vagina, with diphtheritic matter. | Negative. | |
| 67 | June 23 | Rabbit............ | Diphtheritic material put into mouth and throat without scarification. | Negative. | |
| 68 | June 23 | Rabbit............ | Diphtheritic membrane from Smith's case, 5 days old, placed in pocket of muscle of thigh. | Died July 6. | Autopsy immediately after death. Blood full of micrococci; a large ulcer with abundant diphtheritic exudation, composed chiefly of micrococci at seat of inoculation, liver full of small pyæmic abscesses (?). Marrow of bone full of micrococci.<br>Kidney and liver contained some micrococcus emboli; rest of organs normal. |
| 69 | June 23 | Rabbit............ | Diphtheritic membrane same as last. | Died June 26, 71 hours after inoculations. | Blood from ear examined four hours before death contained micrococci, not very abundantly. Autopsy a few minutes after death. Blood from jugular vein full of micrococci; at seat of inoculation an almost gangrenous diphtheritic ulcer, surrounded by widespread œdema of subcutaneous cellular tissue; a few pyæmic abscesses in liver; lung croupous pneumonia and some purulent pleurisy. Rest of organs normal, and not containing micrococci. |

*Sixth series of experiments.—Inoculation with epidemic diphtheritic matter from Ludington*—Continued.

| Number of experiment. | Date. | Animal. | Inoculation. | Result. | Result of autopsy and microscopic examination. |
|---|---|---|---|---|---|
| 70 | June 23 | Rabbit............ | Diphtheritic membrane 4 days old (from case of Nelson), placed under skin. | Was sick, with periods of getting better, until July 11, when it died. | Autopsy some hours after death. Blood contained no micrococci; did not coagulate rapidly; in no way perceptibly abnormal, its seat of inoculation a cheesy lump with micrococci. Liver with small pyæmic echinococci cysts filled with granular matter and pus; widespread tuberculosis of internal organs; no micrococci found in bone marrow and spleen (which were ined). |
| 71 | June 23 | Rabbit............ | Same matter as last put in pharynx by scarification. | Negative. | |
| 72 | June 23 | Rabbit............ | Same matter as last put in eye; conjunctiva scarified and eyelids sewed up tightly. | At first considerable local inflammation about eye, which soon subsided; animal seemingly recovered, but was found dead July 16. | Liver with pyæmic abscesses; other organs normal, and not containing micrococci. |
| 73 | June 23 | Rabbit............ | A piece of diphtheritic kidney (from Roche case), 3 days old, inserted under skin. | June 30, rabbit very ill; died July 1. | Blood taken from jugular (June 30) by means of sealed tubes clotted at once, was full of micrococci. Autopsy some hours after death. Liver studded with pyæmic abscess; spleen swollen and dark; rest of organs normal, and in none of them could micrococci be discovered. |
| 74 | June 23 | Rabbit............ | Same as last............... | Died July 6........... | Autopsy immediate. Blood full of micrococci; large diphtheritic ulcer at place of inoculation, with very profuse membranous exudation. Liver full of pyæmic abscesses. Organs not examined for micrococci. |
| 75 | June 24 | Rabbit............ | Hypodermic injection of about 3 drops of blood taken four days before from a fatal case of diphtheria in Ludington. | Died July 3........... | No micrococci in blood. No lesions discovered elsewhere. |
| 76 | June 24 | Rabbit............ | Same as last............... | Negative. | |
| 77 | June 24 | Rabbit............ | Injected 4 minims of saliva 4 days old. | Died July 11.......... | Autopsy. No micrococci in blood; no evidence of local lesion; internal organs slightly tubercular. |

REMARKS—The term pyæmic abscess, used on several occasions, is meant to express a small collection of pus or cheesy matter made up of débris, cells and micrococci not included in a cyst, with or without evidences of echinococci in them.

An examination of the records just given shows that the Ludington diphtheritic matter acted as a very deadly poison upon the animals inoculated with it. In three rabbits, portions of the membrane were placed in the trachea with uniformly fatal results (Experiments 63, 64, 65). In three rabbits (Experiments 68, 69, 70,) membrane placed under the skin or in the muscles acted as promptly as did that inserted in the trachea. The experiments in which the inoculation of membrane had no effect were those in which the poison was placed upon an open surface where it was liable to be washed off. Such were Experiments 66, 67, and 71, where the vagina and mouth were selected. In Experiment 72, the membrane was more or less imperfectly retained in position by sewing the eyelid over it, and the result was somewhat doubtful.

In two instances (Experiments 73, 74,) instead of using membrane we employed minute pieces of kidney for inoculation, and with precisely the same effect, namely, rapid death with characteristic lesions. Injections of minute quantities of blood and saliva into the veins (Experiments 75, 76, 77) gave, however, entirely negative results, with one very doubtful exception.*

It will be seen that the effects produced were entirely different from those which were obtained previously with Philadelphia matter. The results of the two series of experiments may be summed up in a few words, as in the following proposition: *Whilst inoculation of the rabbit with false membrane from endemic or ordinary Philadelphia diphtheria is rarely followed by rapid systemic infection, the placing of material from cases of malignant epidemic diphtheria in the trachea or under the skin is usually fatal; the characteristic post-mortem lesions consisting in the presence of micrococci in the blood, and sometimes also in the internal organs, along with severe inflammation at the point of injury, where there is produced an exudation resembling diphtheritic membrane, and crowded with micrococci.*

The question which naturally arises at the present juncture is: Is the affection produced in rabbits the same as diphtheria of man? Any one who has carefully studied the able, though not sufficiently known, pamphlet of Drs. Curtis and Satterthwaite, will agree with us in believing that they obtained in some cases results similar to those which were yielded by the Ludington material, but in other instances effects like those produced with Philadelphia diphtheritic material. The portion of their text relating to this matter is so important that we quote it in full:

"In the above described disease we failed to see anything specifically resembling diphtheria as it occurs in the human subject. The whole story seemed to be one of local irritant poisoning, which always tended towards the production of an abscess at the site of inoculation, with greater or less concomitant hyperæmia, ecchymoses, and serous infiltration of neighboring tissues, according to the degree of virulence of the inoculated poison. According, also, to the severity of the primary lesions, the animals would die or survive the immediate effects; and according to the secondary history of the mass infiltrated with leucocytes—according, namely, as the mass was reabsorbed or softened and ulcerated—the animal survived unaffected, or slowly wasted away and died of exhaustion. But it might, not without reason, be argued that a rabbit is a widely different animal from a man, and that a disease induced by subcutaneous inoculation might naturally differ in its manifestations from the same occurring idiopathically; hence, that the described affection of rabbits might still be true diphtheria, although wanting in the specific characteristics of that disease as seen in the human subject. To determine this point we proceeded to try if effects similar to the foregoing would follow the inoculation of a material resembling diphtheritic membrane in its anatomical and chemical character, but yet not only not diphtheritic, but even incapable of producing any noxious effect under circumstances where diphtheritic membrane often proves highly infectious. Such a material presented itself in the scrapings from the upper surface of a somewhat 'furred' tongue from a healthy person. These scrapings, while obviously not infectious when brought in contact with the pharyngeal mucous membrane, yet contain anatomical elements of similar character, and in similar vital condition, to those of the diphtheritic membrane. They also swarm with countless bacteria.

"Such scrapings, inodorous when fresh, acquire a peculiarly offensive fœtid smell even within a few hours. Inoculations with this pulpy material were then made in the usual way, with the following results: Three animals were inoculated with the matter freshly removed. Of these, one died between the fourth and fifth day with a lump in each thigh, in all respects similar to that produced by the diphtheritic inoculation. One died on the fourteenth day, with similar lumps, which had softened and ulcerated; and the third on the twenty-fifth day, with widely extended burrowings of pus and secondary peritonitis. Four other rabbits were inoculated with tongue-scrapings, twenty-four hours old and fœtid. Of these, the first developed a large lump of the usual character in twenty-four hours. This was then removed entire for study, and the animal survived with no further lesion. The other three animals were let alone; all developed the usual lesions, and all died on respectively the fifth, nineteenth, and twenty-fifth days. A third series of two rabbits were inoculated with the mixed scrapings of five successive mornings, which were exceedingly offensive to the smell. One died on the sixth day with the usual lumps, but as this was a young animal from a litter some of which died without having been experimented on at all, it is an open question whether or not the death in this case was due to the inoculation. In the other rabbit lumps developed, which ulcerated and discharged foul matter. The animal suffered also in its general health, but ultimately recovered.

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*There is some reason for suspecting that a primary local disease is a necessity in the production of diphtheria, and that injections of diphtheritic matter into the blood will not cause the disease, unless by embolic arrest and formation of local depots of infection. Experiments upon this point are much needed, and we hope to make them at some future time.

"These series of experiments thus developed the important fact that certain non-diphtheritic and non-infectious matters will, when inoculated upon the rabbit, produce a disease closely similar to, if not identical with, the disease caused by the inoculation of diptheritic membrane, and one, also, equally fatal in its effects. But inasmuch as tongue-scrapings are open to the suspicion of containing some peculiar poison derived from the animal body, we determined to experiment with a substance which should be free from such objection, while still resembling diphtheritic membrane and tongue-scrapings in the matter of being putrescent and swarming with bacteria. We accordingly chose Cohn's fluid, which had passed into a state of decomposition. This fluid is simply a solution in distilled water of ammonium tartrate, potassium phosphate, and magnesium sulphate, to which also a little calcium phosphate is added. Upon exposure in a warm place, bacteria appear in this fluid in great numbers, and out of the salts present new compounds are formed of a strongly putrid smell. Inoculations were made with this putrescent material, as follows: Two animals were inoculated in the usual way with the pulpy sediment forming at the bottom of the bottle, and obtained by straining the fluid. Both developed the usual purulent lumps, but with little attendent irritation or constitutional disturbance. In both, the lumps gradually disappeared by absortion and atrophy, and the animals survived. Four rabbits were inoculated by hypodermic injection with the lower stratum of liquid in another sample of the decomposed fluid. Lumps, as usual, formed at the site of each injection; one animal died on the tenth day, the other three survived. Four rabbits were injected hypodermically with the upper stratum of liquid in still another sample. Lumps again appeared at each inoculated spot, but they were small, and all the animals survived. The same procedure in four other rabbits with a fourth sample of fluid produced like effects in three of the animals, but in the fourth no lumps discoverable by feeling the spot could be found. Fourteen animals in all were thus inoculated with the putrid Cohn's fluid. Thirteen of them developed lesions identical in appearance with the characteristic lesions from inoculations with diphtheritic membranes and tongue-scrapings, but the collateral effects were not so severe, and only one animal died from the effects of the inoculation. In short, then, putrid Cohn's fluid, inoculated upon the rabbit, poisons after the same manner as the diphtheritic membrane, though not to the same measure.

"It would seem, therefore, that the disease produced in the rabbit by inoculations of diphtheritic matter is not only not specifically diphtheritic in character, but not even peculiar to the diphtheritic infection; since a disease essentially similar, if it be not pathologically identical, is producible, though in variable intensity, by inoculations of material at once non-diphtheritic and non-infectious to human mucous membrane, and even, it may be, not of animal origin. This fact being apparently established, the important corollary follows, that pathological and pathogenetic conclusions drawn from the effects of diphtheritic inoculations of the rabbit do not, of necessity, apply to the disease, diphtheria, as it appears in the human subject. The many current hypotheses in the premises, therefore, which rest upon such animal experimentation, are built upon a quicksand.

"This conclusion being accepted, it was plain that to attempt to elaborate the pathology of the diphtheritic process by study of the rabbit's inoculation disease would be a waste of time, and all thoughts of the same were accordingly abandoned. But though the inoculation disease is not necessarily nor even probably diphtheria, yet it is possible, and indeed probable, that the poisonous element in the diphtheritic membrane, which will produce diphtheritic infection in man, is the same kind of thing as that which produces the inoculation disease in the rabbit. Hence it seemed to us to be a useful research to try to discover the nature of the infecting principle, whether of diphtheritic membrane, tongue-scrapings or Cohn's fluid, which produces the inoculation disease."

Notwithstanding the shrewd reasoning of the authority just quoted, the correctness of their conclusion does not seem to us established. The fact that something else besides diphtheritic membrane will produce in the rabbit symptoms similar to those caused by the membrane does not disprove that the disease developed by the diphtheritic inoculation in the rabbit is diphtheria; it may be that putrid tongue-scrapings are capable of acting as a diphtheritic infective matter. In a previous chapter we showed that the micrococci of such tongue-scrapings are not distinguishable from those of diphtheria. Moreover we have proven that almost any substance placed under the skin of the rabbit is capable of producing death, and that such death is preceded by the formation of cheesy lumps; the membrane of malignant diphtheria kills the rabbit rapidly without producing these lumps; evidently the tongue-scrapings, &c., used by Curtis and Satterthwaite, acted like the membrane from our Philadelphia cases, and did not cause true systemic infection.

On the other hand, if we examine the general constitutional symptoms exhibited by the systematically infected rabbit we find they are a progressive failure of strength, with fever, such as are seen in the man suffering from diphtheria. If we examine the local symptoms the similarity is even more close, a membrane not to be distinguished by the microscope from that of diphtheria in the trachea, or if the inoculation has been made in the muscle a local exudation similar in all its elements to this membrane. Drs. Curtis and Satterthwaite seem to rely upon the fact that in inoculated animals membranes do not form, except at the point of inoculation. We do not think this cogent. The cases of diphtheria in which membranes form elsewhere than at the original point of disease are certainly in the minority in man; and according to the best modern pathologist it is probable that these secondary formations are the result of secondary local infections and are not the direct result of the constitutional disturbance. Would any one deny that a case of disease in a child was diphtheria because membrane did not form elsewhere than in the throat?

Finally the post-mortem lesions are not to be distinguished in the rabbit dead of an artificial diphtheritic trachitis and a child dead of malignant diphtheritic trachitis. As therefore the poison is the same in the rabbit and in the man, as the symptoms induced are very similar and the post-mortem results identical, we are forced to believe that the disease produced by the inoculation of the rabbit with malignant diphtheritic membrane is essentially diphtheria.

Before considering further the nature of the diphtheria poison we will report some experiments which we have made to determine whether it is possible to pass the disease from rabbit to rabbit.

*Seventh series.—Inoculations with diphtheritic products from animal to animal.*

| Number of experiments. | Date. | Animal. | Inoculation. | Result. | Autopsy and microscopical examination. |
|---|---|---|---|---|---|
| 78 | June 26 | Rabbit | Piece of heartclot from rabbit No. 7 put under skin. | Died July 4 | Autopsy, some hours after death. External wound healed, with small cheesy lump; no micrococci in blood; organs all tubercular. |
| 79 | June 27 | ....do | Inoculated with false membrane from rabbit No. 2. | Died July 13 | Autopsy, some hours after death. External wound healed, with a very small cheesy lump; organs tubercular; no micrococci in blood. |
| 80 | June 28 | ....do | Put piece of membrane in jugular from rabbit No. 3. | Negative. | |
| 81 | July 6 | ....do | False membrane from rabbit No. 1 put in trachea. | Died July 9 | Autopsy, two hours after death. Blood full of micrococci, also bone marrow; trachea with a moderate amount of pseudo-membrane; lung croupous pneumonia and purulent empyæma; spleen small, atrophied; liver with pyæmic abscesses (?); rest of organs normal, and not containing micrococci. |
| 82 | July 6 | ....do | False membrane from rabbit No. 1 put in trachea. | Died July 14 | Autopsy; large diphtheritic ulcer at point of inoculation, the slough containing all kinds of bacteria, but micrococci predominating; no micrococci in blood, spleen, or marrow of bone; no pyæmic abscesses in liver. |

These experiments certainly show that the membrane obtained from inoculated rabbits is capable of causing death; but they also indicate that its toxic power is not as active as that of the original Ludington diphtheritic membrane, since omitting Experiment 79 as doubtful, in half the cases tuberculosis, and not acute systemic infection, was induced. It will be further seen that this result approaches somewhat that obtained with the diphtheritic membrane from Philadelphia, and that we must consider that the poison grows less active by transmission through the rabbit.

The question now presents itself squarely before us, what are the relations of the micrococci which exist in diphtheria to the disease? Are they the poison of the disease, or in other words are they capable of producing it? The absolute, final answer to this question can only be made by producing disease in the animal by micrococci isolated from the remainder of the diphtheritic poison. The difficulties to be overcome in such an attempt are very apparent. Three classes or lines of experiments at this juncture present themselves:

First. The study of the influence of filtration upon the poison as contained in the diphtheritic membrane.

Second. The study of the action of the isolated micrococci as they are to be obtained from urine.

Third. The study of the action of micrococci raised in culture chambers entirely away from the original poison.

In regard to the first of these methods, it is plain that the attempt must be to filter, as completely as possible, out all solid particles from membrane, rubbed up with water; and also that if it be found that the filtrate is innocuous and the matter remaining on the filter still poisonous, the logical deduction is simply that the poison is particulate and not soluble. It is impossible by this method alone to progress further and prove that the micrococci, and not the bits of fibrin, white blood cells, &c., are the materies morbi.

Under the present head we have no new facts to offer. We have lacked apparatus, time, &c., especially a sufficient supply of diphtheritic membrane to carry out the work. The deficiency is, however, of little importance, on account of the thorough, careful labors of Drs. Curtis and Satterthwaite, from whose pamphlets we quote *in extenso*.

"The next point to be determined was whether the poisonous principle is in solution in the fluid of the inoculating materials or whether it resides in the solid elements of the same. For this inquiry aqueous infusions of the infecting matters were filtered and comparisons made of the effects of inoculation of the filtered and unfiltered fluids. Filtrations were made through various thicknesses of ordinary filtering paper and also through porous clay. The experiments with paper-filtered fluids were as follows: An infusion of diphtheritic membrane was made and filtered through a double paper filter. The filtrate, which was clear and odorless, was injected hypodermically into three rabbits. All survived, two without even any local lesion, but the third with a large lump of the usual character, containing living bacteria, upon one side. None of the animals seemed to suffer in general health. At the same time the unfiltered infusion was injected into three other rabbits, and all of them died before the end of the third day with severe lesions."

"As may be at once seen, the general result of the above inoculations was that paper filtration tended to diminish the poisonous virulence of the infusions. But the experiments were not thorough, for the filtration was insufficient to entirely remove certain of the solid constituents (bacteria) from the infusions. The difficulty was that, from the small quantities of diphtheritic membrane at our disposal, we could never obtain a large enough bulk of strong infusion to permit of repeated paper filtration, such as alone would separate, with reasonable thoroughness, all the solid elements of the infusion. We were forced therefore to turn to other infectious infusions, where the requisite bulk of fluid could be had to test the matter thoroughly. We accordingly took Cohn's fluid and filtered it as follows, fresh filters being used at each successive filtration: Twice through single filters of ordinary gray filtering paper; twice through double filters of the same; once through a triple, and once through a quadruple filter; and, finally, thrice through quadruple filters of fine white filtering paper. The final filtrate, instead of the milky appearance of the original fluid, was but faintly opalescent, and, what was interesting and suggestive, had entirely lost the strong putrid smell of the non-filtered fluid. Under the microscope (one-tenth inch immersion objective of J. Beck) the fluid appeared perfectly clear, except that about half a dozen small bacteria were to be found in each microscopic field. This filtrate was then injected into four rabbits, four other rabbits at the same time receiving injections of the unfiltered fluid. The latter animals all developed the usual lumps at each site of injection, but all those injected with the filtrate remained absolutely unaffected. No lumps whatever could be felt upon the thighs at any period; and, to make sure, the skin over one thigh was snipped on the fourteenth day, and through the "window" thus made the whole subcutaneous territory was thoroughly inspected. Not the slightest lesion was to be found; it could not have been told that the region had been inoculated at all. Here, then, we seem to have positive proof, so far as the experiments went, that thorough paper filtration would remove entirely the infectious element of the putrid Cohn fluid. But here the following possible source of error was acutely pointed out by a friend. During the very numerous filtrations above described, the fluid, falling slowly from the funnel drop by drop, had been submitted to a very thorough reration as well as filtration ; and, since it was conceivable that the infectious element might be a volatile chemical compound, it might be that in the experiment the innocuousness of the filtrate resulted from dissipation of a volatile principle by the aeration, instead of separation of a solid element by the filtration.

"To determine this point, a funnel was plugged with a rubber stopper pierced with a small hole, through which fluid could pass only slowly and drop by drop. Some putrid Cohn's fluid was then passed through this funnel as many times as the number of filtrations of the sample used in the last described experiment. This aerated but unfiltered fluid was then injected into four rabbits, four other rabbits being at the same time injected with the original fluid fresh from the bottle. Lumps were produced at each site of injection in the rabbits treated with the aerated fluid, exactly as in those injected with the non-aerated. This test experiment thus removed the possible flaw in the evidence obtained by the filtration injections, and left no doubt that by the separation of solid elements of infectious infusions by thorough filtrations, the infectious principle tends to be removed.

"Further corroboration was afforded by experiments with a putrid infusion of calf's liver. Injections of the unfiltered infusion produced lumps as usual, but the fluid, when filtered, even through a single filter, failed to produce any effect.

"Simultaneously with the above-described experiments with paper filtrates, injections were practiced with some infusions filtered through porous clay. To obtain such filtrates, a porous clay battery cylinder was made use of. A piece of wide rubber tubing, connected with an exhausting syringe, was slipped over the closed end of the cylinder, and by exhausting the air in the tubing a little of any fluid in the clay cylinder would be drawn through the bottom of the same, of course suffering very perfect filtration in the passage. Infusions of three separate diphtheritic membranes, a sample of putrid Cohn fluid, and the infusion of calf's liver, already mentioned, were severally thus filtered. In all cases the filtrate was perfectly clean, entirely free from odor, and, examined microscopically with a $\frac{1}{10}$ inch lens, apparently totally devoid of all solid elements of any kind. The three filtered diphtheritic infusions were severally injected into three, two, and again two rabbits, the filtered Cohn's fluid and liver infusion each into a single rabbit. Not the slightest sign of a local lesion or of any constitutional disturbance followed any of these injections, while in all cases the unfiltered infusions were found upon injection to be more or less virulent.

"These various experiments thus seemed to demonstrate beyond reasonable doubt that the infectious element in diphtheritic membrane, putrid Cohn's fluid, and the like, is separable by filtration from an aqueous infusion. And when the filtration is thorough, as by means of a clay filter, the removal of all noxious principles from the infusion is apparently absolute. From this fact the inference may be fairly drawn that *the infectious principle or principles is resident in some solid element or elements of the gross material, and cannot be separated therefrom to any recognizable extent by the action of cold water.*"

It is hardly possible that any one can read this lengthy extract without being convinced of the correctness of the experiments made and conclusions drawn. Personal acquaintance with one of its authors makes us sure that the experiments were carefully performed and accurately reported. We considered it fairly established that the poison *of diphtheria is solid and particulate.*

As already stated in some detail in our bibliographical review, Dr. Letzerich has found that if the clear urine of a patient suffering from diphtheria be run through paper filters, and these filters afterward washed so as to remove all possible soluble contaminating matter and then dried, a paper is procured full of micrococci, but containing no other of the urinary elements except it be minute traces of epithelium, &c. This prepared paper Dr. Letzerich found to be as poisonous as is diphtheritic membrane.

In repeating these experiments of Dr. Letzerich we did not wash the filters before inoculation, so that our experiments may not seem to be as conclusive as they otherwise would be. When, however, it is remembered that the poison has been shown to be insoluble, solid, and particulate, it is plain that the failure to wash the filter loses its importance.

*Eighth series.—With filter taken from urine.*

| Exp. | Time. | Animal. | Inoculation. | Result. | Autopsy and microscopical examinations. |
|---|---|---|---|---|---|
| 83 | June 23 | Rabbit.. | Vagina, without erosion. | Negative. | |
| 84 | June 23 | ...do..... | Filter paper in mouth scarified and tied up mouth. | Died June 25, about 36 hours after inoculation. | Autopsy some hours after death. Blood taken by tubes from the jugular vein full of micrococci in large numbers, both free and in zooglaea masses. No membrane in M. M. mouth, larynx, or trachea. Lungs pale and collapsed. Liver full of small abscesses. Other organs normal. No micrococcus emboli found in organs. |
| 85 | June 23 | ...do..... | Filter paper as last. | Negative. | |
| 86 | June 23 | ...do..... | Filter put under skin of thigh. | Died during night of June 25. | Autopsy some hours after death. Blood full of micrococci; white blood corpuscles full of micrococci; numerous balls of them in blood and zooglaea masses also. At seat of inoculation a sloughing ulcer covered with diphtheritic exudation with much œdema around it. Liver with pyæmic abscesses. Other organs normal and not containing micrococcus emboli. |

The experiments just reported show that the filter paper loaded with micrococci from the urine is even more poisonous than the membrane itself. It will be remembered that in no case did we succeed in inoculating with the membrane placed in the mouth of the rabbit; yet one out of two experiments with the filter paper was successful. No vaginal inoculation with any kind of diphtheritic matter has in our hands succeeded, so that the failure of Experiment 83 goes for nothing. In the only remaining trial the paper with the micrococci was placed under the thigh and death occurred in less than three days, the blood being crowded with micrococci and the internal organs markedly affected.

In order to determine whether ordinary urine contains any solid material poisonous to rabbits, we inoculated four of these animals with filter-paper, through which had been passed large quantities of normal urine. In one instance the paper was placed in the trachea, through an artificial opening; in the other rabbits the pellets were put in the muscles. None of the rabbits were sickened. The tracheal wound healed rapidly.

The force of the urine filter experiments seems to us very great. The amount of other solid particles in the urine was so small that it is very improbable that the solid particulate poison which caused the septicæmia was other than the micrococci. As the experiments have been performed by three observers (Letzerich and ourselves) their correctness can scarcely be challenged. They seem to us to prove that the micrococci are either the poison, and by their growth enter the tissues and destroy the blood corpuscles, or else that they by the processes of growth in the body produce a poison which is the true materies morbi, or else that they are saturated with the poison and act as carriers of it.

Our next series of experiments were made to determine whether it is or is not possible to produce diphtheria with the artificially cultured micrococci. In them a piece of blotting-paper, which had been moistened with the culture fluid containing growing micrococci, was placed in the tissues or trachea of the rabbit. The experiments are as follows:

*Ninth series.—Culture inoculations.*

| Exp. | Time. | Animal. | Inoculation. | Result. | Autopsy and microscopical examinations. |
|---|---|---|---|---|---|
| 87 | Aug. 8 | Rabbit.. | Fifth generation of Ludington matter in trachea. | Died Aug. 9... | Autopsy some hours after death. No micrococci in blood; no local or other lesions. |
| 88 | Aug. 8 | ...do.... | As last.......... | Died Aug. 23... | Autopsy. Trachea healed. No micrococci in blood. |
| 89 | Aug. 8 | ...do.... | ....do.......... | Died Aug. 26... | Blood examined just before death; no micrococci in it. Autopsy, pneumonia. |
| 90 | Aug. 9 | ...do.... | Fifth generation from Ludington matter in thigh. | Died Aug. 24... | Autopsy some hours after death. No lesion in solid tissues; no micrococci in blood. |

*Ninth series.—Culture inoculations*—Continued.

| Exp. | Time. | Animal. | Inoculation. | Result. | Autopsy and microscopical examinations. |
|---|---|---|---|---|---|
| 91 | Aug. 9 | Rabbit.. | As last | Negative | |
| 92 | Aug. 9 | ...do | ...do | Died Aug. 27 | Autopsy. General tuberculosis. |
| 93 | Aug. 9 | ...do | ...do | Negative | |
| 94 | Aug. 9 | ...do | ...do | ...do | |
| 95 | Aug. 9 | ...do | ...do | ...do | |
| 96 | Aug. 15 | ...do | Inoculated in the muscle of the thigh with third generation Ludington matter. | ...do | |
| 97 | Aug. 15 | ...do | ...do | ...do | |
| 98 | Aug. 15 | ...do | ...do | Died Aug. 28 | |
| 99 | Aug. 15 | ...do | ...do | Negative | Autopsy some hours after death. No micrococci in blood. |
| 100 | Aug. 15 | ...do | ...do | Died Aug. 29 | |
| 101 | Aug. 15 | ...do | ...do | Negative | Autopsy some hours after death. General tuberculosis. |
| 102 | Aug. 15 | ...do | Inoculated in trachea with third generation of Ludington matter. | ...do | |
| 103 | Aug. 15 | ...do | ...do | ...do | |
| | | | | ...do | |
| 104 | Aug. 15 | ...do | | Died Aug. 17 | Autopsy some hours after death. No micrococci in blood. Croupous pneumonia. No pseudo-membrane in trachea, but a simple catarrhal trachitis. |
| 106 | Aug. 15 | ...do | ...do | Died Aug. 28 | Autopsy. No micrococci in blood; croupous pneumonia; other organs normal. |
| 107 | Aug. 15 | ...do | | Died Aug. 28 | Autopsy. No micrococci in blood; general tuberculosis. |
| 108 | July 18 | ...do | Inoculated with the second generation of the diphtheritic matter in the thigh. | Died July 21 | Blood examined just before death; contained micrococci in considerable quantity, infesting white blood corpuscles and also some free. Autopsy immediately. Filter paper still in position surrounded by an inflamed area, but no pseudo-membrane. Liver does not contain abscesses; marrow of bone containing micrococci both in the cells and free; other organs congested, but no micrococcus emboli. |

An examination of the records of these experiments shows that there is only one in which it can be positively affirmed that diphtheria was produced by the inoculation with *cultured* micrococci. This was the experiment 108, made with the second generation. All the experiments made with the third and fourth generations failed, or at best yielded doubtful results in that after death no distinctive evidence could be found of the existence of false membrane at the place of inoculation or of micrococci in the blood. Fortunately, in experiment 108, the result was decisive; and in a case like the present one positive experiment is not to be overcome by many negative trials. There is, however, a special reason why all the experiments, save the 108th, should have proved unsuccessful. The diphtherrtic matter was two and more weeks old at the time of inoculation, as our first studies were naturally directed to the morphology of the micrococci under culture. It will be shown later on in our memoir that the fungus must have lost some of its vitality. Moreover, we allowed the cultures to grow longer than we should have done. Cultures rapidly made with fresh material would probably be effective beyond the third generation.

It has been established by the labors of Pasteur (address before the International Medical Congress, 1881) and others that fungal organisms are capable of losing their noxious powers under altered conditions of cultivation. For reasons, which shall be detailed hereafter, we believe that this is eminently true of the micrococcus now under consideration. Failure, therefore, to produce diphtheria with the third generation of cultivated micrococci from old stock is no evidence that the micrococci is not the materies morbi of diphtheria. The explanation of such failure is probably to be found in the tendency of the micrococci to relapse into its next stage or state under the more or less defective conditions of artificial cultivation. Then, again, we are convinced that quantity is a very important factor in the action of the diphtheritic micrococcus; that not only must the plant be in an active stage, but that also it must be in sufficient amount at the place of inoculation. The cultivated plant exists in very minute amount as compared with the natural plant, and in our culture inoculations the amount of the plant inserted into the animal was very small as compared with the mass inserted where membrane or kidney was employed. Whatever may be the explanation of the negative results with the third generations, it is certain that we have produced diphtheritic septicæmia with second generation's culture, and we believe that future research will confirm this, and show that *micrococci cause diphtheria by their power of forcing their way into the tissues and by their own excessive vitality overcoming the vitality of those tissues, changing their nutritive processes, destroying them, and finally getting into the blood itself, destroying its white corpuscles and obstructing the circulation.*

Whilst this is our opinion, we do not think that at present it can be considered positively proven that the micrococci themselves are the essential poison, and not simply the carriers of the poison.

A very important practical point to which we have paid some attention is as to whether diphtheritic matter loses its infective power. Curtis and Satterthwaite affirm that their researches show "that there is no relation between inoculable virulence of a membrane and the time after detachment that has elapsed before the material is used for inoculation." The only proof that they offer for this proposition is, however, the fact that membrane three days after removal was found by them as active as that just taken off. Surely this is a very slender foundation for so large a generalization. Our time was for some months so closely occupied with the more immediate necessities of our work that we were not able to make any experiments as to when the membrane begins to lose its activity, but the following experiments show that after a time the membrane even if kept perfectly dry does not lose its contagious powers.

*Tenth series.—Inoculation with two month old, dried Ludington diphtheritic material.*

| Exp. | Time. | Animal. | Inoculation. | Result. | Remarks. |
|---|---|---|---|---|---|
| 109 | Aug. 29 | Rabbit.. | Dried diphtheritic membrane in muscles. | Negative ..... | All these rabbits had been previously inoculated with culture plants. |
| 110 | Aug. 29 | ....do ... | ....do ........... | ....do ......... | |
| 111 | Aug. 29 | ....do ... | ....do ........... | ....do ......... | |
| 112 | Aug. 29 | ....do ... | ....do ........... | ....do ......... | |
| 113 | Aug. 29 | ....do ... | ....do ........... | ....do ......... | |
| 114 | Aug. 29 | ....do ... | ....do ........... | ....do ......... | |
| 115 | Aug. 29 | ....do ... | ....do ........... | ....do ......... | |
| 116 | Aug. 29 | ....do ... | ....do ........... | ....do ......... | |
| 117 | Aug. 29 | ....do ... | ....do ........... | ....do ......... | |
| 118 | Aug. 29 | ....do ... | ....do ........... | | |
| 119 | Sept. 11 | ....do ... | Dried membrane in muscles. | ....do ......... | |
| 120 | Sept. 11 | ....do ... | Dried kidney in muscles. | ....do ......... | |
| 121 | Sept. 13 | ....do ... | Dried membrane in trachea | ....do ........... | |
| 122 | Sept. 13 | ....do ... | ....do ........... | Died Oct. 1 ..... | Autopsy some hours after death. No micrococci in blood; no severe trachitis or any signs of pseudo-membrane; severe double pneumonia. Rest of organs normal and no micrococci found. |
| 123 | Sept. 13 | ....do ... | ....do ........... | Negative. ...... | The last four experiments were primary inoculations, *i. e.*, rabbits had not been previously used. |
| 124 | Sept. 13 | ....do ... | ....do ........... | ....do ........... | |

These experiments do not seem to need comment. The diphtheritic matter employed had originally possessed the most virulent properties. But in sixteen inoculations, four of them into the trachea, not once did it produce any signs of disease. On placing the micrococci in the culture chambers the reason of this was obvious; they had lost their power of rapid growth and were as sluggish as plants taken from a furred tongue—a further evidence of the close connection between the power of growth of the micrococci and the infectious properties of the membrane containing them.

In finally considering the nature of diphtheria the facts which have been established should be carefully thought over. They may be stated as follows:

The micrococci of diphtheria do not differ, so far as observed, from the micrococci of furred tongue, &c., except in their tendency to grow in culture fluids.

The micrococci of furred tongue or ordinary sore throat have a less tendency to grow under culture than have the micrococci of endemic non-malignant diphtheria.

The micrococci of endemic or non-malignant diphtheria have a much less tendency to grow under culture than have the micrococci of malignant diphtheria.

The rapidity of growth of the micrococci is in direct proportion to the malignancy of the case yielding them, and its contagiousness.

On exposure to the air diphtheritic membrane of the most virulent type loses its contagious power, and the micrococci *pari passu* lose their power of growing in culture fluids.

Under successive generations of artificial culture the diphtheritic micrococci lose their growth, activity, and also their power of infecting the rabbit.

It has not been experimentally directly proven, but it is a necessary inference from the two facts just stated, that under certain favoring circumstances the sluggish micrococcus puts on growth—activity, and, in all probability, *poisonous properties.*

Every grade of case can be found in man from an ordinary sore throat, through simple pseudo-membranous angina and trachitis, up to malignant diphtheria.

Any inflammation of the trachea of sufficient intensity may cause the formation of a pseudo-membrane.

A case may begin as one of sthenic "pseudo-membranous croup" and end as one of adynamic "diphtheria," with blood-poisoning; and in cases of this character not infrequently no exposure to contagion is discoverable, and there is clinically every reason to believe that the blood-poison has been developed within the body of the patient. The theory of the disease which we would deduce from these facts is that the micrococcus, which directly or indirectly causes the diphtheria, is not a specific organism different from that common to healthy and inflamed throats, but is an active state of that organism; that certain circumstances outside of the human body are capable of throwing this common micrococcus into this condition of active growth and engendering an epidemic of diphtheria. When diphtheria is thus epidemic the micrococci light upon a throat, and if the throat have little resisting power, as in the child, inflame it or increase a catarrh already existing into a violent inflammation, and also rapidly enter the blood and cause systemic poisoning. On the other hand, a catarrh in a weakly subject may in the beginning be simply an inflammation from cold, but the ordinary micrococci in the throat or mouth, favored by the special conditions, &c., may gradually change from the dormant to the active state, and by and by act upon the throat, and at last force their way into the system and a self-generated diphtheria be formed out of a "cold."

It has already been abundantly proven that there is no specific character detectable in the micrococci of diphtheria. The history of wounds infected with diphtheritic poison and of those infected with hospital gangrene lends further countenance to the idea that diphtheria and certain other septic diseases are really different manifestations of the one affection, the difference in symptoms depending rather upon the difference in the location than in a difference of the nature of the septic process. In order to test this we have made a few experiments. The coming on of our winter work has, however, prevented our investigating the matter further as we otherwise should have done. The experiments performed are as follows:

*Eleventh series.—Inoculation with gangrenous matter.*

| Exp. | Date. | Animal. | Inoculation. | Result. | Remarks. |
|---|---|---|---|---|---|
| 125 | August 28.... | Rabbit........ | Inoculated in trachea with matter taken from a case of spreading gangrene, which destroyed the foot of a man in the Philadelphia hospital; it was full of micrococci. | Died Sept. 2, after suffering 2 days with severe trachitis. | Blood full of micrococci indistinguishable from those of diphtheria; trachea; inflammation with false membrane; liver full of collections of micrococci; other organs not examined microscopically. |
| 126 | August 28.... | .....do......... | As the last............ | Rabbit was ill, but recovered. | |

We do not claim that these experiments are sufficient to establish the identity of diphtheria and other forms of local gangrene, but they certainly favor such a belief. And we would respectfully suggest to the National Board of Health the great necessity of further research, especially upon the relations to diphtheria of scarlet fever, pyæmia, erysipelas, and various septic diseases in which micrococci that seem to be similar to those of diphtheria occur.

UNIVERSITY OF PENNSYLNANIA, *October* 1, 1881.

# APPENDIX No. 2.

## *SPECIAL REPORT TO NATIONAL BOARD OF HEALTH—EXPERIMENTAL INVESTIGATIONS RELATING TO THE ETIOLOGY OF THE MALARIAL FEVERS.*

By George M. Sternberg, *Surgeon, U. S. A.*

Having been instructed by the National Board of Health (letter dated Washington, D. C., February 4, 1880) to repeat the experiments of Klebs and Tommasi-Crudeli, made in the vicinity of Rome—as a result of which they announce the discovery of a *Bacillus malariæ*—by a comparative study, made by the same methods, in a recognized malarial locality in this country, I devoted my time almost exclusively to this work during the months of September, October, and November of last year (1880).

Before recording my own experiments, I shall give some account of the experiments of Klebs and Tommasi-Crudeli, so that the reader may judge of the nature of the evidence upon which their conclusions are founded, and of the bearing of my own investigations with reference to these conclusions.

By the kindness of Dr. John Dell'Orto, an Italian physician practicing in New Orleans, I am now in possession of a translation of the entire memoir, (Studi sulla Natura della Malaria, Roma 1879,) from which I learn that I did not fully appreciate in advance of my own experiments the value attached by these gentlemen to certain evidence which to me seems to be unreliable and secondary in importance as compared with the temperature curve, which, I think it will be generally admitted, must be our main reliance for establishing a diagnosis of malarial fever, especially in the case of an animal which, *a priori*, we would scarcely expect to find susceptible to the influence of the malarial poison.

It seems to me that nothing short of a paroxysmal fever, exhibiting marked periodicity as to the recurrence of the paroxysms, and a sufficient number of them to remove the suspicion of apparent periodicity from accidental causes, can be accepted as proof in an experimental investigation of this nature.

I do not find such proof in the temperature charts of Klebs and Tommasi-Crudeli (Plate 1), nor do I find it in my own charts (Plate 2), and my observations give me little confidence in changes in the dimensions of the spleen, the presence of black pigment and an increase in body weight, as evidence of malarial infection in an animal which, so far as we know, is not susceptible to the influence of the malarial poison when exposed to it in the usual manner in which it manifests itself among the human inhabitants of a malarial region.

In order, however, to do these authors justice, I shall quote from their memoir sufficiently to enable the reader to judge for himself of the nature of the evidence upon which they rely.

I may say in advance that the memoir of Klebs and Tommasi-Crudeli shows a careful and painstaking attention to details, and a manifest desire to be accurate and precise in the statement of facts, which indicates a truly scientific spirit, and induces me to accept, without hesitation, the experimental data which they have recorded, although I am obliged to differ with them as to the value of the deductions which they have drawn from their researches.

### *Extracts from memoir of Klebs and Tommasi-Crudeli, (l. c.)*

"Attention is called to the fact that in the 'Roman fever' it often happens that an intermittent paroxysmal fever is converted into a continued or sub-continued form and entirely loses its characteristic type."

Remark.—A continued fever is produced in the rabbit by the subcutaneous injection of a variety of substances, and this fever sometimes has a remittent character when there is no suspicion of malarial infection.

"The diminution in the weight of the body, which is generally observed in other fevers, is not to be found in malarial fevers, it is only noted at a later stage of the disease. In the first days of the fever, especially when it is of a true intermittent type, the appetite increases, and this explains why there is no decrease in weight. This peculiarity is a characteristic sign of the malarial infection which must be taken into consideration during researches on animals."

Remarks.—I am not aware that the truth of this statement is generally admitted by the profession, and even if we accept it as demonstrated, so far as man is concerned, very carefully conducted experiments with adult rabbits would be required to eliminate the possibility of gain in weight from natural growth or from improved conditions as to food and comfort.

In my experiment No. 6, in which a rabbit was injected with putrid urine, and suffered an attack of fever which produced death in twelve days, a gain in weight of 103 grams occurred. This was a young rabbit, which was growing rapidly at the time the experiment was made. I have observed a marked increase in other cases in which the fact was not verified by weighing.

"During a septic process the form of the spleen is modified in such a way as to present a rounded aspect, or a rotundity of its edges, while in the malarial infection the splenic tumefaction appears like a regular uniform swelling of the whole organ, and the transverse sections resemble those of a normal spleen, but larger in every direction."

REMARKS.—I have not been able to discover any marked differences in form between the spleens of rabbits which have succumbed to unquestionable septicæmia and those in which an attempt was made to produce malarial infection by the subcutaneous injection of the material obtained by the methods of Klebs and Tommasi-Crudeli from malarial localities near the city of New Orleans. As to the size of the spleen, which I have compared directly, by weight, with the weight of the body (see Experiments 4, 6, 7, 9, 13, 14, 16, 28, and 33), instead of adopting the plan of Klebs and Tommasi-Crudeli, which consists in measuring the length, breadth, and thickness for the purpose of comparison, I have found it to be larger in undoubted cases of septicæmia (Experiments 6 and 7), produced by the injection of putrid urine and my own saliva, than in other cases in which a solution of fish gelatine or of water inoculated with organisms from swamp-mud was the material injected (Experiments 9, 15). In rabbit No. 8, which received three successive injections (Experiments 8, 10,) and 19) of swamp culture-solutions, and which finally succumbed to an injection of water containing surface mud from the gutter in front of my laboratory, the spleen was only $\frac{1}{2461}$ part of the weight of the body, while in rabbit No. 7 (Experiment No. 7), in which my own saliva was injected, the proportion was $\frac{1}{671}$. This proportion seems to depend to a considerable extent upon the age of the animal, being greater in young rabbits.*

"Another characteristic sign of the malarial infection is the black pigment from the blood. This sign is not alone observed in the pernicious forms. In less serious cases of the intermittent type of long duration, black pigment may be found in the spleen and sometimes in the marrow of the bones. In the gravest forms of malarial fever this pigment is found in large quantity through all the circulatory system and in many of the organs."

REMARKS.—In my post-mortem examinations of rabbits which have died from the effect of subcutaneous injections, I have been in the habit of examining blood from the cavities of the heart and the tissue of the liver and spleen as soon as these organs were removed from the body. I have never found black pigment in the blood, but have found it in abundance in the spleens of several septicæmic rabbits, in which there could be no suspicion of malarial complication, *e. g.*, in rabbits which died in Philadelphia in January and in Baltimore in April as the result of the subcutaneous injection of human saliva (*l. c.*). Masses of orange-colored pigment are still more commonly found in the spleens of septicæmic rabbits, and in one instance orange-colored pigment was found at one extremity of a spleen, which retained its normal color, while the other extremity, which presented a dark discoloration, contained and abundance of black pigment. I cannot doubt that these masses represent broken-down blood corpuscles, and that the black pigment only differs from the orange-colored as the result of some chemical change which I am inclined to think occurs, sometimes at least, post-mortem.

"The lack of suppuration, or the small amount of suppuration at the point of injection," is spoken of as an indication of value in establishing a diagnosis. My results in this particular have varied considerably, according to the nature of the injected material. When the material used has been my own saliva, or a little surface mud from the gutters of New Orleans, or the "rough material" from the surface of an "artificial marsh," (*Vide* Experiments 9, 13, 20, &c.), diffuse cellulitis has commonly resulted with an exudation into the cellular tissue of bloody serum swarming with bacteria and possessing highly infectious properties. In an experiment in which pus

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*Since writing the above I have examined the spleens of a large number of rabbits, the victims of septicæmia (see special report to National Board of Health in Bulletin No. 44, of April 30, 1881), and I have found the greatest diversity in the size and appearance of this organ. Sometimes it presents no appreciable changes, but commonly it is more or less swollen and discolored, and this tumefaction varies greatly, both as to its amount and as to the resulting shape of the organ. Sometimes it is enlarged in all its dimensions, and at others the length is increased without a corresponding increase in breadth. In a recent post-mortem I found the spleen of a small rabbit (weight 24 ounces) to weigh 34 grains. This animal died from the subcutaneous injection of $1.25^{cc}$ of hay-infusion, which had been kept in a culture-oven for 24 hours, and which contained *Bacillus subtilis* and micrococci in abundance.

was injected but slight local inflammation was produced, but quickly fatal results followed, and metastatic deposits of pus were found in the liver. In my experiments with fish-gelatine solution, containing organisms developed as a consequence of inoculation with swamp-mud, &c.—à la Klebs and Tommasi—I have sometimes had considerable abscesses form at the point of injection, and these have sometimes pointed at the center of the belly, the most dependent situation, and sometimes have been absorbed, leaving a little mass of cheesy material in their place. These abscesses have often been quite small, but they have rarely failed to follow the injection of the fish-gelatine solution. My observations, therefore, in this particular, do not correspond with those of Klebs and Tommasi-Crudeli.

. As a result of preliminary culture experiments made with material obtained from malarial localities in the vicinity of Rome, our authors discovered a Bacillus which appeared to them to be quite different from *Bacillus subtilis* (Cohn) of hay infusions, and from *Bacillus anthracis* (Koch), and which may be characterized as follows:

"Small rods, of 5 to 10 micromillimetres length, which during their evolution become converted into tortuous filaments, which divide into joints by the formation of clear spaces in the protoplasm, or more seldom by means of separating membranes. These filaments produce series of very short joints on the surfaces exposed to the action of the air, and spores are developed in their interior. The spores are situated in the center, or toward the extremities of the joints; they may also be found in the center and at the extremities at the same time; when the division in joints does not occur, they multiply, they become smaller, and fill up the interior of the filaments with a granular mass. As we obtained repeatedly the same forms from these cultures made with the purest gelatine solution, and from several different specimens of soil taken from malarial localities, we conjectured that this plant could perhaps be the bearer of malaria."

The question will at once be asked as to whether I have found the so called *Bacillus malariæ* in malarial localities in the vicinity of New Orleans.

I have certainly found bacilli and minute filamentous algæ, closely resembling the different forms described and figured by Klebs and Tommasi-Crudeli, but see no good reason for conferring upon these particular forms the special distinction of being named *Bacillus malariæ*, in preference to any other of the minute vegetable organisms with which I have found them to be associated.

Figs. 1, 2, and 3, Plate I, are photographic reproductione of the plates which accompany the memoir of Klebs and Tommasi-Crudeli, and represent their so-called *Bacillus malariæ*. I must refer the reader to the original work for a detailed description of the various organisms observed by the authors, and for an account of their culture experiments made with a view to elucidating the life-history of their *Bacillus malariæ*.

A glance at Plate I will show that my photo-micrographs (Figs. 4 to 9) represent a number of minute algæ, some of which resemble very much the forms drawn by Klebs and Tommasi-Crudeli. After a careful study of their figures and of their written descriptions, I do not, however, feel justified in saying positively that I have met the identical organism described by those authors, and, indeed, I am not satisfied from their account that they have not included several distinct forms (species?) under the name of *Bacillus malariæ*. Their description of little rods having a granule or spore at each extremity, and often a third at the center, corresponds with the organism shown in Fig. 3, Plate II, which is from a gelatine culture solution inoculated with swamp mud in accordance with their method. I have recently (May, 1881) found the same form in culture liquids (chicken bouillon, &c.) exposed in the biological laboratory of Johns Hopkins University, Baltimore, and am inclined to believe that this is simply an advanced stage in the development of *B. termo*. The same appearance of terminal spores is seen in Fig. 4, Plate I, which is also from a culture experiment made in Baltimore. I have frequently observed rods like these in diarrhœal discharges of men, and of rabbits—the subjects of my experiments.

Many of the rods seen in Fig. 7, Plate I, presented the same appearance under the microscope, although the terminal spores (?) are not distinctly seen in the photograph. This specimen is from the surface of a glass slide exposed over an "artificial marsh" in New Orleans, and it, perhaps, corresponds more nearly than any other of my figures with the drawings and descriptions of our authors.

Fig. 6, Plate I, resembles very closely Fig. 1, copied from the memoir of Klebs and Tommasi-Crudeli. This also is a development from air-borne spores in a culture fluid exposed in the laboratory of Johns Hopkins University in Baltimore.

Fig. 5, Plate I, represents two common species of minute algæ, found in abundance in the gutters of New Orleans. The larger is an Oscillatorea: the smaller, made up of short joints, should probably be referred to Bacillus or Leptothrix.

Fig. 8, from the surface of swamp mud near New Orleans, closely resembles the last described, and Fig. 9, which seems to be identical with the last, was found in the discharges from my own bowels at the time I was engaged in these researches. It was observed on several occasions and in considerable abundance. I may say that I was in my usual health at the time, with the exception of a slight diarrhœa, which did not interfere with my work.

Our authors describe *Bacillus malariæ* as made up of "small rods of 5 to 10 micromilimeters in length, which, during their revolution, become converted into tortuous filaments, &c.

Tufts of tortuous filaments, like those seen in Figs. 7 and 8, Plate II, were found in abundance in my gelatine culture solutions inoculated with swamp mud according to the method of Klebs and Tommasi-Crudeli. I did not, however, find time to trace the life-histories of these various organisms, and cannot say whether these tortuous filaments were developed from rods, or if they "divide into joints by the formation of clear spaces in the protoplasm."

It is extremely desirable that the life-histories of all of these minute algæ should be worked out; but, in the absence of definite proof that any one of them is entitled to the special distinction of being called *Bacillus malariæ*, I have not considered it necessary to take time for this study, which, it seemed to me, could be employed to better advantage in attacking, by experimental methods, problems of greater immediate importance.

The fact that the organisms described by Klebs and Tommasi-Crudeli and those represented in my photo-micrographs are from a malarial locality does not, of course, prove that they are *peculiar to* malarial localities, and far more extended observations will be required to demonstrate the truth or falsity of such an hypothesis. In my own experiments the same organisms were found when the gelatine solution was inoculated with earth taken from the public squares in the city of New Orleans as when swamp mud was used for this purpose.

Our authors having, as they believe, discovered a Bacillus peculiar to malarial localities, say:

"It only remains now to proceed to the experimental investigations on animals in order to appreciate the value of this suggestion."

The normal temperature of the rabbit was found to be 39.5 C. (103.1 Fah.).

*Researches with material taken from the Pontine Marshes* were made upon rabbits Nos. 1, 2, 3, 4, and 5 (see temperature charts, Plate III). The details given in relation to Nos. 1 and 2 will alone be given, as it is believed that this will suffice to fairly represent the nature of the evidence which has been adduced, and I must refer the reader to the original memoir for fuller information.

"*Parallel researches with the mud of Caprolace.*—For these researches we experimented on rabbits 1 and 2. At ten o'clock a. m., April 16, 1879, $1.6^{cc}$ of water, which had been obtained three days previously from the mud of Caprolace, was injected under the skin of No. 1, and immediately after $0.6^{cc}$ of the liquid contained in culture-tube No. 1 was injected in the same way into rabbit No. 2. In this tube, which contained very pure gelatine solution, we had put on the 11th of April a very small quantity of the mud of Caprolace, after which the extremity of the tube was carefully closed with cotton. The tube was kept for three days on a stove at a temperature of 30° to 35° C.*"

REMARK.—The precaution of carefully closing the mouth of this tube with cotton was doubtless a proper one, but it can hardly be considered of vital importance when we consider that the gelatine solution was exposed to inoculation with atmospheric germs during the time it was being introduced, and that so far as the germs of bacteria are concerned it is probable that the mud of Caprolace itself contained a full assortment of germs of the more common and widely distributed forms, and especially of *B. termo* and *Bacillus subtilis*. Gelatine solution is a putrescible fluid. A temperature of 30° to 35° is favorable for the development of the bacteria of putrefaction; and it can scarcely be doubted that whatever other organisms were present and whatever may have been the special rôle of each, the common bacteria of putrefaction must have developed abundantly under such circumstances.

"Rabbit No. 1 was killed by blood-letting, and an autopsy was made at once, with the following results: At the place of injection, right side of lumbar region, a callosity was observed 4 centimeters in length and 3.5 in width, formed of white connective tissue having a fibrous appearance, and some very large blood-vessels filled with hard and reddish-brown colored thrombi. All around this callosity the subcutaneous tissue was œdematous. The liquid of this œdema, taken immediately by means of capillary tubes, contained a great quantity of small movable corpuscles of an oval or round form, and shining, some of which show on two opposite sides small obtuse prolongations. Besides these, immovable filaments were seen of the maximum length of 5.9001 μ, and of the width of 0.7143 μ. The lymphatic glands of the mesentery were much swollen, and contained a great quantity of whitish liquid. The spleen was enlarged and measured $55^{mm}$ in length, 9 in width, and 4 in thickness. Examination of the tissue of the spleen showed a large quantity of dark-brown pigment, in irregular masses. Upon adding to the tissue of the spleen some aqueous humour from the anterior chamber of the eye of the same rabbit (recognized previously as perfectly normal), a great number of small, round corpuscles were seen moving with activity. No alteration was found in the other organs of this animal. In order to determine the nature of the round, movable corpuscles found in the spleen, two culture-cells were prepared. In the first was placed the serous liquid of the lymph, in the second a small quantity of spleen pulp diluted with aqueous humour. Both were placed in an oven, and kept at a temperature of 30° to 35° C. Before making the preparation the culture-cells were heated to 120° C., in order to kill all living organisms that might be attached to them. At the end of twenty-four hours the first preparation contained immovable filaments with shining granules (spores), and some small movable rods, sometimes united in couples; also some free oval corpuscles, similar to those contained in the filaments. * * * In the second culture-cell there were, besides many free spores, some filaments with homogeneous protoplasm. These and especially the smallest, could only be seen with objectives of excellent definition, such as the one-twelfth and one-eighteenth inch of Zeiss, lighted with the apparatus of Abbe. Later, they could be seen well with lower powers.

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*The temperature of these rabbits, after the injection of above mentioned liquids, as shown in curves 1 and 2, Plate II. The weight of No. 1 at the outset of the experiment was 1,560 grams, and of No. 2, 1,904 grams.

"We see, then, that in both rabbits which were used for this research a fever of intermittent type appeared as a consequence of the injection of the aforesaid substances (Plate I, curves 1 and 2). Soon after the injection a rise of temperature to above 40° C. was verified; on the following day it fell a little lower than the normal; on the third day there was a slight increase; on the fourth a new paroxysm of fever appeared, with an evening temperature of 40.85° C. in No. 1, and 40.6° in No. 2. After the fifth day the course of the disease takes a different form: Rabbit No. 1, into which we had injected 1.6$^{cc}$ of water drawn from the mud of Caprolace, maintains a high temperature, with slight variations, during forty-eight hours; while No. 2, into which only 0.6$^{cc}$ of the culture made from the same mud was injected, shows a slight elevation of temperature, with slight quotidian remissions on the fifth, sixth and seventh days. On the eighth there was a normal temperature; on the ninth a little below the normal in the morning, with a slight rise in the evening. On the tenth we put rabbit No. 2 aside for another research. We see, then, the fever of No. 1 becoming continuous after the second paroxysm, while in No. 2 an almost normal condition follows the second paroxysm. This difference corresponds with the difference in the quantity of the material injected.

"With regard to the anatomical alterations found in No. 1, which was killed during the paroxysm of fever, the following are worthy of note: First, the lack of suppuration at the point of injection; second, the increase of all the dimensions of the spleen, especially of the length (55$^{mm}$, while the normal mean is 38.75$^{mm}$, which gives to the index of the spleen a value of 1298, almost double the normal (664 ) ); third, the appearance of the same organisms in the liquid injected, at the place of injection, in the spleen and in the lymph. Neither the course of the disease nor these anatomical alterations correspond with those of putrid or septic fever. The increase in the weight of the body between the first and second paroxysms is also worthy of attention."

REMARK.—It is believed that the quotations already made and the temperature charts given in Plate I sufficiently indicate the nature of the evidence upon which Klebs and Tommasi-Crudeli depend to establish their announcement of the discovery of a true *Bacillus malariæ*, and without further remarks I shall proceed to detail the experiments made by myself with a view to confirming, if possible, the results obtained by them by similar experiments conducted at a distant malarial locality.

## EXPERIMENTAL RESEARCH.

The locality selected as a suitable place from which to obtain samples of swamp mud for experimental purposes was a point in the suburbs of New Orleans, in the "third district," where the track of the Mobile Railroad débouches from the city to enter the extensive swamp in rear of it, which extends towards Lake Pontchartrain. Suburban dwellings of the poorer sort are situated on the very margin of this swamp, and my friend, Dr. Gustav Deveron, who kindly aided me in making this selection, assures me that cases of malarial fever are common in this part of the city, especially during the months of September, October, and November.

My experiments were commenced in May, by collecting from the surface of dry swamp mud the organic pellicle which is found in such situations. A small quantity of this material was placed in a bottle with distilled water; after a few days this water was found to contain a considerable quantity of spherical bacteria in zooglœa masses.

*Experiment No.* 1, *May* 12.—Five cubic centimeters of this fluid were injected into the cellular tissue of rabbit No. 1. Result, entirely negative. The animal showed no signs of ill-health.

*Experiment No.* 2, *May* 16.—Thirty gallons of swamp air passed through 5 cubic centimeters of distilled water, which was then injected into the cellular tissue of rabbit

No. 2. Result, entirely negative so far as appearances were concerned. No temperature observations were, however, taken.

*Experiment No.* 3, *May* 22.—Five cubic centimeters of Cohn's fluid, containing numerous bacteria (*B. subtilis*), injected into the cellular tissue of rabbit No. 3. Result, the animal remained in good health.*

As there was no satisfactory evidence that the malarial poison was present in the air passing over the swamps near New Orleans at this season of the year, further experiments were postponed until the autumn.

On the 19th of September, 1880, I obtained two specimens of surface mud from the locality above indicated, two specimens from the river *batture* in front of the city, and two from public squares (Lafayette and Congo) in the city of New Orleans.

These samples were placed in six tin vessels having perforated bottoms, each four inches in diameter and six deep. These vessels were placed in shallow porcelain dishes containing water, for the purpose of keeping the mud in the cylindrical tin vessels constantly wet, and producing an "artificial marsh," such as is described by Klebs and Tommasi-Crudeli. I have not considered it necessary in these experiments or in the culture experiments with fish-gelatine solution, to be detailed hereafter, to resort to artificial heat, as was done by Klebs and Tommasi-Crudeli, believing that natural conditions should be maintained as far as possible, and assuming that the normal temperature of the atmosphere, which was from 78° to 85° Fahrenheit at the time these experiments were in progress, was a favorable one for the development of the hypothetical malarial germ, inasmuch as numerous cases of malarial fever gave evidence of the presence of the poison in the vicinity of the swamp from which I obtained my material, and the conditions of temperature at this place evidently could not be very different from those in my laboratory, not more than two miles distant. I also departed from the directions of Klebs and Tommasi-Crudeli, who placed their "artificial marshes" in a ventilating chimney, by placing mine in an open window, so that the direct rays of the sun might fall upon them during the day-time, believing that by so doing I should maintain more nearly the identical conditions under which malaria is given off from a natural marsh.

On the 30th of October a new supply of surface mud from the swamp (same locality) and of sandy loam from the river *batture* was placed in four of the tin vessels already described, and these were kept in an open window of my laboratory as before.

The organisms which appeared upon the surface of the mud in these different vessels were studied by various methods during the time the experiment was in progress—about six weeks—and photomicrographs were made of all that it was thought might possibly be of interest in connection with the investigation in hand. One of the most successful methods of collecting these organisms for study was found to be the following: A thin glass cover, carefully cleaned, was lightly placed upon the surface of the moist mud, and left for twenty-four or forty-eight hours. It was then picked up with forceps and placed upon a clean glass slide over a small drop of distilled water. Very commonly minute drops of condensed moisture would be found upon the lower surface of the thin cover, and in this case it was not necessary to use distilled water in the examination. For the purpose of arresting the motion of infusoria and active bacteria, either for photographing or to render their examination with high powers more satisfactory, I very frequently used a weak solution of iodine instead of the distilled water. (Iodine, gr. 1; iodide of potass., grs. 2; distilled water, grs. 100.)

Upon bringing the under surface of a thin cover, which had been exposed and mounted as indicated, into the focus of a good objective, a variety of minute algæ were usually discovered. The most common forms are shown in Figs. 5 and 7, Plate I, and in Fig. 6, Plate II.

These minute algæ, belonging to the Palmellaceæ and Oscillatoriaceæ, together with a few diatoms and infusoria, and a greater or less number of bacteria, were commonly found adherent to the under surface of the cover glass and were in a satisfactory position for immediate study, for staining and photographing, or for mounting permanently in a preservative fluid.

Instead of leaving the cover in position for a day or two, very satisfactory specimens may be obtained for immediate examination by taking a clean cover and pressing it gently with forceps against the surface of the mud. When the proper amount of pressure is used the organisms adhere to it without any earthy matter being picked up. A less satisfactory method, but one which I have employed in imitation of Klebs and Tommasi-Crudeli, is to add a little of the surface mud to distilled water in a test-tube, and, after shaking and subsidence of the heavier portion, to examine the suspended particles. In this case it is necessary to take samples from different parts of the tube, as the organisms near the surface will often be found to differ from those near the bottom.

The following notes will show the character of the organisms found in the samples of mud which were under observation in the experiments here recorded. The various specimens were numbered as follows:

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* The Cohn's fluid used in this experiment had been added to water through which swamp air had been passed.

No. 1, from edge of swamp near Mobile Railroad.
No. 2, from edge of swamp near Mobile Railroad.
No. 3, from Lafayette square, New Orleans.
No. 4, from Congo square, New Orleans.
No. 5, from river *batture* in front of city.
No. 6, from river *batture* in front of city.

Nos. 3, 4, 5, and 6 were taken from supposed non-malarial localities for comparison with Nos. 1 and 2 from malarial localities.

*September* 19.—A little mud from surface of No. 1 was added to distilled water and shaken up in a test-tube. After the earthy matter had subsided the suspended particles were examined with Beck's one-fifth inch and Zeiss's one-twelfth inch objectives, with the following result: Much amorphous vegetable *débris*, which renders the water in the test-tube quite opaque; mingled with this are bodies, motionless or possessing brownian movements only, which resemble bacilli, rod-bacteria, and micrococci or spores, but which it is difficult, in the absence of vital movements, to distinguish with certainty from the vegetable *débris* which simulates all these forms.

*September* 20.—The water in the test-tube has cleared up by deposition of the vegetable *débris*. Upon the surface of the deposit at the bottom of the tube are a few diatoms and *Euglena viridis*. In the supernatant water no moving bodies can be detected, but a few extremely minute spherical bodies are seen, of uniform size (less than 1 $\mu$), single and in pairs. The pairs are evidently joined by some transparent substance, which is not visible, but which holds these spores (?) at a fixed distance one from the other.

REMARK.—Similar spherical bodies, united in pairs, have been obtained, but not in great numbers, in aspiration experiments made in the vicinity of the swamp and also in front of my laboratory in New Orleans. I believe them to be the spores, or more properly, conidia, of one or more species of bacteria, and that the invisible material which holds them together is the transparent remnant of the filament or rod in which they were developed, consisting, perhaps, only of a very delicate cellular envelope, or possibly of a jelly-like substance resulting from the softening down of this membrane. It is impossible to determine with certainty the species or even the genus of Schizomycetes to which these spores should be referred, but as the spores of known bacilli are considerably larger, and the filaments of the spirilla would be longer, if extended, than the distance between these spores, it is probable that they should be referred to Bacterium or Vibrio. That the spores of the bacteria of putrefaction were present in this water was proved later by the rapid development of these organisms in a solution of fish gelatine inoculated with it.

*September* 21.—In addition to organisms already mentioned this water contains oval ciliated infusoria and long oscillating filaments.

*Examination of Specimen No.* 2, *September* 19.—A little surface mud was shaken up in a test-tube with distilled water, and after deposition of earthy matter microscopic examination made with same results as obtained in preceding examination. In addition a few elongated filaments were found, having a spore in one end (*Bacillus subtilis*). On the surface of the mud in this test-tube are numerous oscillating bacilli containing a spore at each end; others have three and some even four spores in a linear series, also a few diatoms, monads, and unicellular algæ.

*September* 21.—The bacilli with included spores (*conidia*) observed yesterday are very active, and three species of filamentous algæ (*Oscillatoriaceæ*) are observed as well as *Euglena viridis*, and the monads and diatoms seen yesterday.

*Examination of Specimen No.* 3, *September* 21.—A few actively moving spherical bodies, single and in pairs.

*Examination of Specimen No.* 4, *September* 21.—Much amorphous vegetable *débris*, some minute micrococci having vital movements, and some of same dimensions grouped in fours; also, a few actively moving monads.

*Examination of Specimen No.* 5.—Same as above; also, *Euglena viridis*.

CULTURE EXPERIMENTS WITH ABOVE SAMPLES OF EARTH.—On the 21st of September a solution of fish gelatine was made according to the directions of Klebs and Tommasi-Crudeli. This solution, after being filtered, was maintained at the boiling point in a water bath for more than an hour. Half an ounce of the gelatine solution was then placed in each of six small beaker glasses, which were labeled culture Nos. 1, 2, 3, 4, 5, and 6, and were respectively inoculated with a small quantity of the earth from the surface of artificial marshes bearing corresponding numbers. The beakers, of which the capacity was two ounces, were placed upon pieces of plate-glass having a ground surface and covered with a small glass circle. Each one was then covered with a bell-glass (apparatus of Lister).

In obtaining specimens of the fluid in these glasses for microscopic examination it was my custom to take a drop or two from the top or bottom, as desired, by means of a pipette. To prevent inoculation of one culture fluid by organisms from another, the pipette was heated in the flame of an alcohol lamp before using it anew.

I shall give a somewhat detailed description of the organisms found successively in these different culture experiments before proceeding to an account of the results obtained by injecting these fluids into the cellular tissue of rabbits.

*September* 22.—Microscopic examination of culture fluids with Beck's one-fifth and Zeiss's one-eighteenth inch objectives.

*No.* 1 contains numerous highly refractive spherical bodies of 1 $\mu$ diameter, motionless, solitary or in pairs; also at surface, *B. termo*.

*No.* 2 contains the same refractive spherical bodies (spores of bacili?) at the bottom of the fluid, and upon the surface, *B. termo*, and micrococci, solitary and in chains of two or three; also a few rod-bacteria larger than *B. termo* (*B. lineola?*).

*No.* 3 contains at surface *B. termo*, actively moving spherical bodies and a few rods. At the bottom numerous rods of Bacillus (sp.?).

*Nos.* 4 and 5.—The same as above, but the bacteria are longer and resemble those found in acid urine of yellow-fever patients. (See "The Bacteria," Plate III, Little, Brown & Co., 1880.)

*No.* 6.—The same as above, and in addition long, flexible, transparent filaments, and rods having spores at each extremity resembling the *Bacillus malariæ* of Klebs and Tommasi-Crudeli.

*September* 23, *No.* 1.—The refractive spherical bodies are more numerous than yesterday at the surface of the liquid, where they are associated with *B. termo;* at the bottom are numerous rods having a diameter of 0.7 $\mu$ and a length of 1.5 to 3 $\mu$, which contain a refractive granule (conidium or spore) at each extremity, and in some instances a third in the middle. (See Fig. 3, Plate II.)

*No.* 2.—Same as above, also upon the surface a few rods considerably larger than those described, and filled with granules. At the bottom flexible filaments with granular contents having a serpentine movement (*Vibrio serpens?*).

*No.* 3.—Same as No. 2.

*No.* 4.—The same, and also numerous amœbæ, having a transparent rapidly-flowing protoplasm, containing many granules (apparently bacteria, upon which they have been feeding).

*No.* 5.—The same bacteria as in No. 1.

*No.* 6.—The same, and some long, slender filaments, less than 1 $\mu$ in diameter.

*September* 24, *No.* 1.—The same bacteria as before described.

*No.* 2.—At bottom radiating masses of rods and spores, and on surface a mycoderma of *B. termo*.

*No.* 3.—All of the forms of bacteria heretofore described, oval ciliated infusoria and amœbæ, some active and some encysted (Fig. 5, Plate II). Also elongated bacteria of same diameter as those on surface, exhibiting serpentine movements (*Vibrios*).

*No.* 4.—Bacteria, amœbæ, &c., as above described; also some oscillating filaments.

*No.* 5.—The same, and a few ciliated infusoria.

*No.* 6.—Numerous bacteria, with granular contents, having a length of 3 to 5 $\mu$ and a thickness of 1 $\mu$ form a thick veil (mycoderma) upon the surface of the liquid. (See Fig. 1, Plate II.) *Bacterium termo* also present.

A second culture experiment, marked No. 6–2, was started this day by inoculating fresh gelantine solution with a minute drop of fluid from the surface of No. 6, with the purpose of cultivating the organism above described by itself.

*September* 26.—No. 6–2 is covered with a mycoderma of the same bacteria previously found in No. 6. (See Fig. 1, Plate II.)

*No.* 3.—Contains, in addition to organisms previously described, bacilli, with spores at one extremity, probably as a result of the development of rods from the refractive spores heretofore mentioned. Also bacilli in leptothrix chains and spirilla (*S. volutans?*).

*No.* 2.—Also contains, in addition to organisms previously described, some amœbæ and large oval cells containing granules. (See Fig. 5, Plate II.)

A thin glass cover examined this day, which had been left upon the surface of artificial marsh No. 1 for forty-eight hours, had adhering to its under surface diatoms (*Navicula*) minute filamentous algæ (*Oscillatorieæ*) and bacteria (*B. termo*). A thin cover from artificial marsh No. 6 had adhering to it long, slender filaments and rods with spores at each end closely resembling those figured by Klebs and Tommasi-Crudeli under the name of *Bacillus malariæ*. (See their Fig. 3, Plate I.)

*September* 27.—In addition to organisms already described, gelatine solution No. 1 was found to contain numerous tufts of slender, flexible filaments. (See Fig. 7, Plate II.)

REMARKS.—It will be observed that up to the present time a variety of different organisms have made their appearance upon the surface of my artificial marshes, in the test-tubes containing water and earth from these marshes, and in the fish-gelatine culture solutions. Many of these, such as the diatoms, amœbæ, ciliated infusoria, euglena, and the larger oscillatorieæ, are widely distributed and tolerably well known forms. When we come to the more minute algæ and the bacteria, which I have described and photographed, I am not prepared to speak with any great amount of confidence, as there is still much confusion and uncertainty in the descriptions given of these forms, even by such authorities as Cohn, Nägeli, and others, who have devoted the most attention to them.

There is no doubt, however, that the bacteria of putrefaction were present in all of my gelatine culture experiments, as the odor of putrefaction was given off from these solutions within a day or two after inoculation with earth from the sources specified. This was to have been expected, *a priori*, as the gelatine solution is extremely prone to putrefactive changes, and the bacteria of putrefaction are so universally distributed that it would probably be difficult to obtain a sample of earth from any source on the surface of the earth, in temperate regions, which should be quite free from these organisms or their germs. Klebs and Tommasi-Crudeli, who used artificial heat in their experiments with their so-called "artificial marshes" (30–35° C), say:

"The most remarkable result of this arrangement was that almost immediately a great quantity of organisms contained in the grounds and in the muds died. * * * No more moldiness was formed at the surface of the ground or of the vessels, and the phenomena of putrefaction stopped in the marshy muds, while they reached a high degree of putrefaction whenever the same muds were kept under bell-glasses."

The arrest of the phenomena of putrefaction did not dispose of the bacteria of putrefaction already present, and these must have been introduced into the fish-gelatine solution and other liquids inoculated with these muds, and could scarcely have failed to multiply in them.

In my culture experiments *B. termo* took the precedence of all other organisms as to the time of appearance and rapidity of development, with the single exception of No. 6, inoculated with sandy loam from the river *batture*, in which the form represented in Fig. 1, Plate II, was the predominant form, *B. termo* being also present. The rapid increase of these bacteria near the surface of the liquid gave to the previously transparent gelatine solution a clouded appearance. Soon a delicate veil (mycoderma) formed upon the surface consisting of motionless rods of varying length. In some of these rods refractive points were to be seen near the extremities, which are believed to be conidia or spores. These are well shown in Fig. 3, Plate II, in which rods of varying length may be seen, some having a spore at each extremity and others a third one in the center. This photograph is made from a collection obtained from the bottom of culture No. 1, but the same form was present in all of the culture fluids, and, as already stated, I suspect it to be a stage in the existence of *B. termo* and to represent the formation of spores in this organism. In the course of a few days the active life of *B. termo* ceases in these solutions of gelatine and the liquid resumes its transparency, all of the little rods being deposited on the bottom of the vessel. In the meantime the liquid, which was colorless, has acquired a pale amber tint, and has a disgusting glue-factory odor.

Shining oval and spherical bodies of about 1 *u* diameter, believed to be the spores of bacilli, were observed in the different culture liquids upon the first examination. These seemed to increase in number, and after two or three days rods commenced to make their appearance, some uniform in diameter and joined in leptothrix chains, others having an expanded spindle-shaped extremity. (See Fig. 9, Plate II.) It is believed that this form represents the development of the spores, already referred to, into rods, and that this organism is the widely-distributed *Bacillus subtilis* which has been carfully observed by numerous microscopists. Vibrios also made their appearance in all of the solutions in greater or less numbers. The specimens represented in my photograph (Fig. 4, Plate II) are from culture No. 3. At this time also commenced to appear at the bottom of all of these solutions the tufts of radiating flexible filaments shown in Figs. 7 and 8, Plate II. What relation, if any, these flexible filaments bear to the vibrios, Fig. 4, and to the bacteria, Figs. 2 and 3, I am unable to say, but I suspect that they represent a phase in the development of these organisms, or possibly of the bacilli shown in Fig. 9.

In culture No. 6 and in No. 6–2 the bacteria shown in Fig. 1 continued to be the most abundant form up to the time that the following injection experiments were made:

### EXPERIMENTS UPON RABBITS.

On the 29th of September, eight days after the commencement of the above-described culture experiments, the following injection experiments were made:

*Rabbit No.* 4.—Injected into cellular tissue of left flank $0.75^{cc}$ of gelatine culture solution No. 1, first stirring up from the bottom the deposit containing organisms above described.

*Rabbit No.* 5.—Injected in the same way (with hypodermic syringe) $0.75^{cc}$ of culture fluid No. 6–2, first shaking it up so as to distribute through the liquid the deposit at the bottom and the mycoderma upon the surface (*B. lineola?*).

*Rabbit No.* 6.—Injected in the same way 0.75$^{cc}$ of urine, containing *B. termo*, which had been inoculated two days previously with a drop of putrid meat juice.

*Rabbit No.* 7.—Injected in the same way 0.5$^{cc}$ of saliva containing epithelial cells, &c., from my own mouth. The following day, September 30, rabbit No. 8 received an injection into the cellular tissue of left flank of 1.26$^{cc}$ of gelatine culture No. 1 (same as rabbit No. 4.)

Nos. 4, 5, 6, and 7 were young rabbits of the same litter, and weighed respectively 474, 320, 390, and 304 grams. No. 8 was a full-grown male, weighing 1,922 grams.

In the temperature observations made upon these rabbits, and in subsequent experiments, the thermometer was introduced into the rectum, and usually three daily observations were made, viz, at 8 to 9 a. m., at 12 to 1 p. m., and at 5 to 6 p. m.

The more frequent observations, hourly in some cases, made by Klebs and Tommasi-Crudelli, do not seem to have disclosed any marked oscillations of temperature not shown by three daily observations; and it was quite impossible for me to attempt more frequent observations without additional assistance, unless I should neglect the quite as important daily microscopical examination and photographic record of the organisms found in my culture experiments. As the result of several observations upon healthy rabbits, the mean normal temperature was found by Klebs and Tommasi-Crudelli to be 39.5° C. (103 1° Fahr.)

This corresponds very nearly with my own observations repeated on various occasions, but it must be borne in mind that variations above and below the normal mean are quite common in healthy rabbits, and that considerable variations may result from trivial causes. Thus the temperature of six healthy rabbits was found (October 15), when they were first brought to my laboratory in New Orleans, to vary from 102.3° to 103.6°; and the temperature of a rabbit upon which three daily observations were made for several days, and which did not receive any injection, and was apparently in perfect health, varied from 102° to 104° Fahr.

This considerable variation in the temperature of healthy rabbits, due chiefly to external causes, but perhaps attributable sometimes to fear, violent exercise, &c., is even more marked in those animals which have received an injury of any kind, or those in which fever has been produced by the subcutaneous injection of any pathogenic material.

As a quickly fatal result followed the injections made in the case of rabbits Nos. 4 and 7, and that without any evidence of paroxysmal fever, remittent or intermittent in character, I shall first detail the history and post-mortem appearances of these animals, and will later call attention to the character of the temperature records in rabbits 5, 6, and 8, of which charts are given. (Plate IV.)

### *Experiment No.* 4.

*Rabbit No.* 4.—Injection at midday, September 29, temperature at 7 p. m., 103°. September 30, 8 a. m., 103.2°; 2 p. m., 104°; 7 p. m., 104.1°. October 1, 8 a. m., temperature in the rectum below 95° (the lowest point marked on the register of the thermometer). The animal is dull and feeble, and drags its hind legs when it attempts to move. 11 a. m., can no longer sit up, but lies upon its side; has dilated pupils, stertorous respiration, and venous and capillary congestion of ears. 11.30 a. m., contracted pupils, death; rigor mortis ten minutes after death.

*Post-mortem examination at* 12.45 *p. m.*—Stomach and bowels normal, filled with food and fæces, bladder full, liver dark colored and congested, weight 18 grams; spleen of normal size and appearance, weight 0.32 grams; auricles of heart and large veins filled with dark blood; brain and meninges congested, lungs normal.

*Microscopical examination.*—At the point of injection some slender filaments and numerous micrococci, single, in pairs, and occasionally in chains of three. Blood from left auricle and the spleen pulp contains the same organisms; leucocytes contain numerous granules of the same diameter as the micrococci referred to.

*October* 2.—Microscopical examination of culture cell, put up yesterday, containing gelatine solution and a little of the cheesy material from point of injection; shows granular *débris*, slender, flexible moving rods of various lengths, and micrococci.

Microscopical examination of culture cell containing blood from auricle, mounted yesterday at the time of post-mortem; shows micrococci, solitary, in pairs, in chains of three, and in sarcina-like groups of four.

The bladder of this rabbit, filled with limpid urine, was removed, after tying a ligature around the urethra, and placed in a clean saucer under a bell-glass. Microscopical examination of the contents, October 2, showed it to contain granular matter, epithelium from the bladder, and a few micrococci, solitary, in pairs, and in groups. No odor of putrefaction.

When the post-mortem of rabbit No. 4 was made a small portion of spleen pulp, taken from the interior of the organ with instruments previously heated to redness to destroy adherent germs, was carefully placed in pure gelatine solution in a beaker and covered with glass plate and bell-glass, as in previous culture experiments. (Lister's apparatus.) This was labeled "Spleen culture No. 1." Upon examining this liquid, October 3, it was found to contain an abundance of *B. termo*, micrococci, and a few vibrios. Examined again October 6, it proved to contain *B. termo* in abundance, and at the bottom the same organism in a quiescent state, and containing terminal spores as shown in Fig. 3, Plate II. This solution was again examined October 15, with the following result: The same bacteria above described, also smaller bacteria, micrococci, and numerous bacilli, with a single terminal spore. The effect produced by the injection of this fluid into the cellular tissue of rabbit No. 13 will be detailed hereafter. A later examination of this fluid, October 18, showed it to contain the above-described organisms and torula-like chains of bacilli, each joint of which contained a spore; also extremely slender filaments, mostly motionless; but some had a serpentine motion and exactly resembled the filaments subsequently found in the blood of rabbit No. 16. (*Septic vibrio* of Pasteur.)

REMARKS.—It is believed that this rabbit died of acute septicæmia, although the symptoms might be interpreted as due to a congestive form of malarial fever. Results obtained in subsequent experiments confirm, however, the first supposition rather than the latter.

### *Experiment No.* 7.

*Rabbit No.* 7.—Injection at midday, September 29 ($0.5^{cc}$ of saliva). Temperature, 7 p. m., 107.2°. September 30, 8 a. m., 104.8°; 2 p. m., 104.5°; 7 p. m., 106°. October 1, 8 a. m., 106.5°; 2.30 p. m., 106.70°; 7 p. m., 104.2°. October 2, 9 a. m., temperature, 98°. Posterior extremities stiff, pupil normal, respiration normal, vessels in ears not congested. Death at 12 m. Post-mortem immediately. Diffuse cellulitis extending from seat of injury, with effusion of bloody serum and inflammatory adhesion of integument to subjacent tissues. Liver not congested, weight 5.2 grams; bladder, empty; intestines, rather empty; hardened fæces in rectum; heart, flaccid; auricles not distended; spleen weighs 0.45 grams.

*Microscopic examination of serum from cellular tissue.*—Contains blood corpuscles, granular leucocytes, *B. termo*, and micrococci, single and in torula-chains.

*Microscopic examination of spleen pulp.*—Red blood corpuscles, granular leucocytes, *B. termo* abundant, many shining spores and groups of micrococci.

*Spleen culture No.* 4.—A portion of the spleen of this rabbit was placed in gelatine solution (Lister's apparatus), and microscopic examination made the following day, which demonstrated the presence of a few motionless bacilli.

*October* 5.—The same solution contains numerous *B. termo*, and bacilli with spores at one extremity. (Fig. 9, Plate II.)

*October* 18.—The solution contains the organisms above described, the rods of *Bacillus* being more numerous, some with and some without spores; also free spores, vibrios, and jointed filaments, of which each joint contains a spore resembling in size and appearance the free spores described. The filaments have the same diameter as the rods of bacilli described, and are like those found in spleen culture No. 1.

*October* 24.—The fluid now contains many oval spores of the bacilli previously described, and slender flexible filaments having a serpentine movement. This fluid was used on October 27 for two injection experiments on rabbits 10 and 11. (See page ——).

REMARKS.—It cannot be doubted that in the case of rabbit No. 7 the cause of death was diffuse cellulitis and septicæmia, produced by the subcutaneous injection of ten minims of saliva from my own mouth. Whether this rapidly fatal form of septicæmia was produced by the secretions of my mouth with the contained organisms and histological elements (epithelial cells and mucous corpuscles) because of an unusual septic condition of these secretions due to personal or atmospheric conditions of a temporary character, or whether the same result would follow as a rule at other times and in other places, can only be determined by additional experiments.*

My experiments thus far having demonstrated that fatal septic results were produced by the subcutaneous injection of my own saliva, and suspecting that the pathogenic properties of the fish-gelatine solution (experiment No. 4) were of the same nature, I subsequently made a variety of experiments with a view to throwing light upon this question. These experiments I shall report in the order which seems most convenient, without reference to the dates at which they we made, and first I shall give *fatal cases.*

### *Experiment No.* 13.

*Rabbit No.* 12, *October* 7, 9 *a. m.*—Injected into right flank $1.35^{cc}$ of water shaken up with a little material scraped from the surface of gutter-mud in front of my laboratory (corner Gravier and Rampart streets, New Orleans). Temperature, 1 p. m., 106°;

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* BALTIMORE, *June* 12, 1881.—For results of an experimental research undertaken for the purpose of settling the question here raised, see Special Report to National Board of Health in Bulletin No. 44,

6 p. m., 107°; October 9, 8.30 a. m., 106°; 1 p. m., 106°; 6 p. m., 109°. October 10, 9 a. m., found dead. Post-mortem examination shows diffuse cellulitis and gangrenous sloughing of the integument and subjacent tissues of the right side of the belly. So extensive has been this sloughing that the intestines are exposed. A very offensive odor of putrefaction is given off from the gangrenous tissues. The rabbit must have died early in the night, and was so offensive that no further examination was made.

### *Experiment No.* 14.

*Rabbit No.* 13, weight 1,088 grams.

*October* 15, 10 *a. m.*—Injected $1^{cc}$ of spleen culture No. 1 into left and the same amount into cellular tissue of right flank. Temperature, 1 p. m., 104.4°; 6 p. m., 102.9°. October 16, 8.30 a. m., 104.2°; 1 p. m., 103°; 6 p. m., 101.5°. October 17, 9.30 a. m., 95°; 12 m., dead. Post-mortem examination immediately. Diffuse cellulitis extending from point of injection. The cellular tissue is infiltrated with bloody serum, which swarms with bacteria; bladder empty; stomach and bowels moderately full; spleen normal in appearance, weight 0.39 grams. The spleen pump contains micrococci (?) motionless, single, and in masses; liver congested and dark colored, weight 25.5 grams, contains many blood corpuscles, some fat granules and granular leucocytes. Blood from heart contains granular leucocytes and a very few moving spherical bodies, micrococci (?). Cut surface of lung tissue, granular leucocytes, but no organisms recognized.

REMARKS.—The granular condition of the leucocytes here referred to is the rule in these cases of acute septicæmia in the rabbit, and is believed to represent a degenerative change in the protoplasm, which seems to consist at the outset in the formation of little masses, probably albuminoid, or rather regular size, and resembling micrococci. Later a further change seems to occur, resulting in the formation of fat globules. The rather uniform size and the appearance of being sometimes joined in pairs or chains which these granules present, raises a suspicion that they may be vegetable organisms, and possibly this may sometimes be the case, a point which could scarcely be decided by the optical appearances alone. But in my efforts to solve this question by means of reagents and staining solutions, I have not found any support for the hypothesis that they are of a vegetable nature. In certain instances the protoplasm of the leucocytes from the lungs, liver, and spleen of these septicæmic rabbits was found to be diffluent, and to contain numerous actively moving (brownian movement) granules of uniform size, possibly micrococci (?).

### *Experiment No.* 20.

*Rabbit No.* 18, *October* 18.—Injected into cellular tissues $2^{cc}$ of water to which had been added, October 10, surface mud from artificial marsh No. 2. This had been shaken up in a test tube and then allowed to stand until the date of the injection. Temperature, 1.30 p. m., 104°; 6 p. m., 103.5°. October 19, 8.30 a. m., 105°; 1 p. m., 106°; 5.30 p. m., 106°. October 20, 8.30 a. m., 100.6°; 1 p. m., dead. Post-mortem examination immediately. Diffuse cellulitis extending from point of injection. Bloody serum from cellular tissue swarms with bacteria (*B. termo*, bacilli, and micrococci). Liver weighs 534 grams, congested. No organisms recognized in scrapings from freshly cut surface of liver, in blood from heart, or in spleen pulp. Liver contains much fat.

### *Experiment No.* 16.

*Rabbit No.* 15, *October* 15.10 *a. m.*—Injected into cellular tissue $1.5^{cc}$ of pus culture No. 9 (pus from abscess in flank of rabbit No. 9, which died October 7, was added to fish gelatine solution on the same day and placed in a beaker under bell-glass). A microscopical examination made just before injection showed this solution to contain numerous minute micrococci. Temperature of rabbit, 1 p. m., 105.8°; 6 p. m., 105.2°. October 16, 8.30 a. m., rabbit found dead. Post-mortem examination at once. Cellular tissue infiltrated with bloody serum, which swarms with bacteria and has an offensive odor; bladder full of limpid urine; stomach and intestines normal and full; liver weighs 58 grams, and has a mottled appearance due to leather-colored hue of lobules, defined by red outlines of congested intralobular vessels, but surface shows an abundance of oil-globules and fatty degeneration of liver cells; many leucocytes in which the protoplasm is diffluent and contains numerous minute granules exhibiting active brownian movements; spleen dark colored and softened, weight 0.78 grams, contains numerous red corpuscles, granular leucocytes and masses of red pigment, also some free oil globules; no organisms recognized. One lung congested; auricles and large veins distended with dark blood. Microscopic examination of blood from auricle; red corpuscles normal, some white corpuscles swarming with actively moving granules like those in liver (micrococci ?), a few refractive granules in serum, *and* *numerous slender filaments* which move across the field with a serpentine motion, pushing aside the red corpuscles in their course. These filaments are less than 1 $\mu$ in diameter and vary in length from 50 $\mu$ to twice the length of the field of the microscope (Zeiss's one-eighteenth inch objective and low eye-piece). Scrapings from cut surface of lung contained red corpuscles, leucocytes containing moving granules (brownian movement) like those in liver and blood from heart, and actively moving (brownian) granules of same kind in masses external to leucocytes and apparently escaped from them. The organisms found in serum from cellular tissue are vibrios in great number, *B. termo* and micrococci. Some liver tissue compressed under glass cover shows the flexible filaments (*Vibrio serpens?*) found in blood from auricle in great number and exhibiting very active serpentine movements. Under the influence of iodine solution the flexible filaments are found to consist of a central portion stained by the iodine and a transparent sheath not colored. The central portion is broken in places, but not regularly jointed. These filaments are not changed by soaking for twenty-four hours in solution of caustic potash or, in strong liquor ammonia. They are deeply stained by aniline violet, and are without doubt vegetable organisms.*

REMARKS.—The results thus far detailed are tolerably uniform, and there seems no reason to doubt that the fatal effects which followed the injection of the different experimental liquids employed were due to septicæmia, accompanied or preceded, in every instance, except in rabbit No. 4, by diffuse cellulitis extending from the point of injection. The septic fluids which gave rise to this result were: water containing surface earth from artificial marsh (experiment No. 20); water shaken up with algæ, &c., scraped from surface of gutter mud in front of laboratory (experiment No. 13); saliva, from my own mouth (experiment No. 7); fish gelatine solution from swamp culture No. 1 (experiment No. 4); spleen culture No. 1 (experiment No. 14); pus culture No. 9 (experiment No. 16). A different result occurred in the case of rabbit No. 9, which died of tetanus four days after receiving the injection below indicated.

## *Experiment No.* 9.

*Rabbit No.* 9, weight 1,689 grams.

*October* 3, 10 *a. m.*—Injected into left flank 1.26$^{cc}$ of water, shaken up with surface mud from artificial marsh No. 2, of September 30; 8 p. m., temperature 105.8°; October 4, 9 a. m., temperature 102.4°; 3 p. m., 102,8°; 7.30 p. m. 102.6°. October 5, 9 a. m., 102°; 2 p. m., 102°; 7 p. m. 102.4°. October 6, 9 a. m. 101.5°; 1 p. m., 103°; 7 p. m., 104°. October 7, 9 a. m., 103.2°; 1 p. m., dead. It will be observed that after the rise of temperature on the evening of October 3, which has uniformly followed injections made with various fluids, the temperature did not differ materially from the normal until the day before death, when the morning temperature was one and a half degrees below the normal, followed by a rise during the course of the day to 104°, or 1° above the normal. The rabbit commenced to show some rigidity of the muscles of the posterior extremities on the 5th. This had considerably increased by the evening of the 6th, and on the morning of the 7th there was tetanic rigidity of all the muscles of the body, attended with opisthotonos and locked jaws. The pupils were widely dilated, respiration was rapid, and convulsive movements occurred when the animal was disturbed. Death occurred at 9.45. The temperature in the rectum shortly before death was 104°, *shortly after death it was found to be* 111.5°. The animal weighed 1,534 grams, a loss of 155 grams since it was previously weighed, at the outset of the experiment. A circumscribed abscess containing stinking pus was found at the point of injection. A drop of this pus was used to inoculate the gelatine solution of *pus culture* No. 9, which subsequently proved so quickly fatal to rabbit No. 15. The bowels were distended with gas, serous fluid and fæces. Weight of spleen 0.51 grams, weight of liver 60 grams. Auricles and large veins distended with blood. Brain and spinal cord normal in appearance. Microscopic examination of serum from bowels shows much granular matter, but no bacteria recognized. Pus from abscess contains numerous bacilli and micrococci.

*October* 8.—Microscopic examination of blood from auricle placed yesterday in a culture cell; a cluster of spores and numerous sprouting mycelial filaments of *Penicillium glaucum* are found on the edge of the drop of blood. (I think it probable that this resulted from the use of forceps not properly cleaned, which had been used a day or two before in handling rotten banana covered with *Penicillium*.) Microscopic examination of pus, placed yesterday in culture cell, shows numerous bacilli and micrococci in irregular groups, and in sarcina-like masses.

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* BALTIMORE, MD., *June* 12, 1881.—I am now satisfied that this is the organism described by Pasteur as the vibrio of septicæmia. He says, "*There are as many different septicæmias as there are different vibrios* * * *. In septicæmia the vibrios do not appear in the blood until the last thing, but in this liquid one of them takes a peculiar aspect, often longer than the diameter of the field of the microscope, and so transparent that it easily escapes observation; when, however, it is once perceived it is easily found again, *flexible, climbing, and removing the blood globules as a serpent moves the grass in the bushes*," &c. (Charbon and Septicæmia, C. R. Ac. des Sc. LXXV, 101-115).

To ascertain what effect gelatine solution not containing bacteria might have, when injected into the cellular tissue of a rabbit, the following experiment was made:

### *Experiment No.* 18.

*Rabbit No.* 17; weight, 1,906 grams.

*October* 15, 10 *a. m.*—Injected into cellular tissue of right flank $1^{cc}$ and into left flank $1^{cc}$ of gelatine solution from stock-bottle containing numerous flocculi of mycelial filaments (*Penicillium glaucum*), but no bacteria. Temperature, 1 p. m., 104.5°; 6 p. m., 105°; October 16, 8.30 a. m., 102.4°; 1 p. m., 103; 6 p. m., 103.8°; October 17, 9.30 a. m., 102.2°; 6 p. m., 102°; October 18, 8.30 a. m., 102.5°; 1.30 p. m., 103°. The rabbit having shown no symptoms of ill-health, except the slight febrile movement immediately following the injection, was now used for another experiment.

Wishing to further test the septic properties of gutter water and the organisms found in it, the following experiments were made: First, to ascertain whether septic poisoning would be produced by the injection of the larger organisms, *Euglena*, ciliated infusoria, filamentous algæ, &c., found in standing but not putrid water, some masses of confervoid algæ (chiefly *Spirogyra*) were gathered from a little pool of standing water in front of my residence, where, owing to a depression in the grading of the street and a neighboring water-plug, I have ready access to a fresh-water acquarium, from which I have been able to obtain at any time during the summer a great variety of organisms, animal and vegetable, for microscopic examination. This locality is but one square and a half from my laboratory, in front of which the septic material was obtained which proved so rapidly fatal to rabbit No. 12; but in this instance my material was obtained from the slimy surface of the mud, which was sometimes covered with water and again exposed to the direct rays of the sun, and putrefactive changes were doubtless occurring in the mass of animal and vegetable matter mixed with the earthy material found on the sides and bottom of a foul gutter.

The bright green filaments of *Spirogyra* and the organisms adhering to them, which furnished the material for the following experiments, were, on the contrary, taken from comparatively pure water, and were not undergoing putrefactive changes.

*October* 25, 8.30 *a. m.*—Injected rabbit No. 8 (subject of previous experiments not yet recorded), with $1.26^{cc}$ of the first washings from mass of filamentous algæ collected in front of residence as above described, and rabbit No. 10 with $1^{cc}$ of fluid obtained by bruising in a mortar with a little rain-water the well-washed filaments of *Spirogyra.*

### *Experiment No.* 24.

*Rabbit No.* 8.—October 25, temperature, 1 p. m., 105.8°; 6 p. m., 103.6°; October 26, 12 m., 103.8°; 6 p. m., 103.8°; October 27, 8.30 a. m., 103°; 2 p. m., 104.2°; October 28, 8.30 a. m., 103.6°; 2.30 p. m., 104°; October 29, 8.30 a. m., 103.5°; 2.30 p. m., 103.2°; October 30, 8.30 a. m., 103.2°; 3 p. m., 103°. No symptoms having resulted from the injection beyond a temporary rise of temperature immediately following the operation, no further observations were made until November 4, when the animal was made the subject of another experiment.

### *Experiment No.* 25.

*Rabbit No.* 10, *October* 25, 8.30 *a. m.*—Injected $1^{cc}$ of water containing chlorophyll and protoplasm from filaments of *Spyrogyra*, prepared as above described, into cellular tissue of right flank. Temperature, 1 p. m., 105.5°; 6 p. m., 104.8°; October 26, 12 m., 104.2°; 6 p. m., 104.8°; October 27, 8.30 a. m., 103.6°; 2 p. m., 104.4°; October 28, 8.30 a. m., 103°. At this time the rabbit, being apparently in good health, was made the subject of another experiment.

The above experiments seeming to show that septic results do not follow the subcutaneous injection of infusoria, algæ, &c., not undergoing putrefaction, a further experiment was undertaken to see if septicæmia would follow, after the heavy rains and cool weather which has prevailed in the interim, upon repeating the experiment which gave such a promptly fatal result in the case of rabbit No. 12. For this purpose I collected, on November 4, a quantity of slime from the surface of gutter mud, from which the water had recently receded (shortly after a heavy rain), by scraping off the superficial layer with my pocket knife and placing it in a bottle. This was shaken up with water, and poured into a filter consisting of four thicknesses of fine filtering paper. The filtrate was perfectly transparent, and was used in the following experiment:

### *Experiment No.* 29.

***Rabbit No.* 5** (subject of previous experiment, but now apparently in good health).—Injected into cellular tissue of flank. $1.26^{cc}$ of above-mentioned filtrate. Temperature, 5.30 p. m., 106°; November 5, 9 a. m., 104°; 3 p. m., 105°; November 6, 8.30 a. m., 104°; 3 p. m., 104°; November 7, 10 a. m., 103.5°; November 8, 9 a. m., 104.2°; 2 p. m., 104°; November 9, 10 a. m., 104.8°; November 10, 3 p. m., 105.2°; November 11, 3 p. m., 106°; November 12, 8.30 a. m., 105°; November 13, 8.30 a. m., 105.6°; November 14, 10 a. m., 105°; November 15, 2.30 p. m., 103.6°; November 16, 2.30 p. m., 103.8°. Observations discontinued, but rabbit remained in apparent good health.

### *Experiment No.* 30.

***Rabbit No.* 8.**—Subject of former experiments but now in apparent good health; has, however, two circumscribed abscesses at site of former injections. November 4, 12 m., injected $1.26^{cc}$ of unfiltered water shaken up with scrapings from surface of gutter mud as above described. Temperature, 5.30 p. m., 105.2°; November 5, 9 a. m., 103.8°; 3 p. m., 105°; November 6, 8.30 a. m., 104.5°; 3 p. m., 104°; November 7, 10 a. m., 106°; November 8, 9 a. m., 104.2°; 2 p. m., 99°. The animal is very sick; has a watery discharge from left eye, which swarms with bacteria. Blood from ear contains granular leucocytes and a large amount of free granular matter, no organisms recognized. November 9, 8 a. m., found dead; post-mortem examination immediately; several cheesy masses the size of filberts at points of former injections; a few drops of greenish pus containing amorphous particles of sand, earthy matter, and many minute bacteria at site of last injection; inflammatory adhesion of integument, but no cellulitis beyond this; stomach and bowels moderately full; spleen normal in size and consistence, weight 0.78 grams; liver congested, weight 42 grams; a small amount of fluid in pericardial and pleural cavities; lungs congested; lungs and heart covered with a deposit of lymph, and lungs adherent to chest walls in places; contents of large intestine examined and found to contain numerous spherical and rod bacteria, and bacilli having a spore at each end like those described and figured by Klebs and Tommasi-Crudeli; fluid scraped from freshly-cut surface of liver contains granular leucocytes, some with moving granules (brownian) and an abundance of fat globules and granules of various sizes. The spleen pulp contains masses of orange-colored pigment. No organisms recognized.

Microscopic examination of water used in the above experiment, made November 10, gave the following result: *Euglena viridis*, diatoms, severals species of filamentous algæ, including one resembling Kleb's *Bacillus malaria*, *Zooglœa ramigera*, and a variety of bacteria. The filtered water used to inject rabbit No 2 was found the following day (November 5) to have on its surface a multitude of minute bacteria and active monads.

REMARKS.—The above experiments seem to show that the fatal septic results which followed the injection in the case of rabbit No. 8 were due to something particulate removable by filtration; yet the filtered liquid produced a continued fever, lasting for several days in the case of rabbit No. 5. The very rapidly fatal result, attended by cellulitis and gangrenous sloughing of the tissues in the vicinity of the puncture, which occurred in the case of rabbit No. 12, may have been due to a greater intensity of the septic poison during the hotter weather of the early part of October, when this experiment was made, or, possibly, to a partially protective influence resulting from the previous injection of septic fluids into the cellular tissue of rabbit No. 8. As the latter case was complicated with pleurisy and pericarditis, believed to be a result of the last injection, but possibly sequelæ of former injections, it is not possible to decide these questions without additional experiments.

To ascertain whether my own saliva retains the septic properties which produced a fatal result in so short a time in the case of rabbit No. 7, the following experiments were made:

### *Experiment No.* 31.

***November* 12, 9 *a. m.***—Injected $1.26^{cc}$ of saliva from my own mouth into left flank of rabbit No. 10. This rabbit has a circumscribed abscess the size of a walnut at the site of last injection, but seems to be in good health. Temperature, 2.30 p. m., 105.6°; November 13, 9 a. m., 105.2°; November 14, 10 a m., 103.8°; November 15, 2.30 p. m., 104°; November 16, 2.30 p. m., 104.2°.

***November* 21.**—The animal has shown no signs of ill-health except the slight amount of fever immediately following the injection.

### *Experiment No.* 32.

***Rabbit No.* 11, *November* 12, 9 *a. m.***—Injected into left flank $1.26^{cc}$ of saliva from my own mouth. Temperature, 2.30 p. m., 104°; November 13, 9 a. m., 104.6°; November 14, 10 a. m., 102.5°; November 15, 2.30 p. m., 104.2°; November 16, 2.30 p. m., 104°.

*November* 21.—The animal has not shown any signs of ill-health since the injection.

As a negative result followed in the cases just detailed, the question arises whether this result, so different from the rapidly fatal effects produced by the injection of the same fluid in September (rabbit No. 4), is to be ascribed to a protection enjoyed by these animals which have already been the subject of experiments with septic fluids, or to a loss of the septic properties which the secretions of my mouth proved to possess during the hot weather. To test this matter the following experiment was made:

*Experiment No.* 35.

*Rabbit* No. 20.—A large female rabbit, not previously used in these experiments, weight 2178 grams. November 18, 11 a. m., injected into cellular tissue of right flank $2^{cc}$ (in two places) of saliva from my own mouth. Temperature, 5.30 p. m., 105°; November 19, 8.30 a. m., 103°; 2.30 p. m., 103.2°; November 20, 8.30, found dead. Post-mortem examination immediately. Diffuse cellulitis with effusion of bloody serum about point of injection. This serum is swarming with bacteria. Liver weighs 72.5 grams; contains much fat and numerous bacteria. Spleen weighs 1.81 grams. Spleen pulp contains a quantity of pigment granules and numerous bacteria. Blood from auricle contains bacteria.

REMARKS.—It is evident that my saliva still retains its septic properties, and the inference is that rabbits No. 7 and 8 did not fall victims to septicæmia because of the protective influence of previous injections of septic fluids.

To further test the septic properties of gutter mud the following experiment was made:

*Experiment No.* 34.

*Rabbit No.* 19, a full-grown male, not used in previous experiments.

*November* 18, 11 *a. m.*—I injected $1.26^{cc}$ of water shaken up with surface slime scraped from the gutter mud in front of laboratory. The night before was the coldest of the season. Temperature 5.30 p. m., 105°; November 19, 8.30 a. m., 105.2°; 2.30 p. m., 105°; November 20, 8.30, 103.5°; November 21, 10 a. m., 103.5°. November 22, 8.30 a. m., rabbit found dead. Post-mortem examination shows diffuse cellulitis extending from point of injection, with effusion of bloody serum which swarms with bacteria.

To ascertain whether the septic culture fluids, which, in October, produced speedy death in rabbits Nos. 13 and 15, still retain their poisonous character, the following experiments were made:

*Experiment No.* 33.

*Rabbit No.* 16.—Subject of previous experiments.

*November* 12, 12 *m.*—Injected into left flank $1^{cc}$ of pus culture No. 9 (the same fluid which proved quickly fatal to rabbit No. 15). This fluid had been undisturbed for a considerable time, and care was taken to take up in the syringe only the transparent supernatant fluid, leaving the deposit at the bottom undisturbed. Temperature, 2.30 p. m., 104.8°; November 13, 9 a. m., 103.8°; November 14, 10 a. m., 104°; November 15, 2.30 p. m., 103.8°; November 16, 2.30 p. m., 103.8°. November 21, the animal remains in apparent good health.

As the negative result in this case might be ascribed to protection due to previous injections, or to the absence of organisms in the undisturbed upper portion of the fluid of my culture experiment, the following experiment was made:

*Experiment No.* 37.

*Rabbit No.* 22.—A young rabbit (less than two months) not previously injected.

*November* 18, 11 *a. m.*—I injected $0.5^{cc}$ of pus culture No. 6 into cellular tissue of right flank. The fluid was thoroughly stirred before filling the syringe so as to include the organisms deposited upon the bottom of the beaker. Temperature, 5.30 p. m., 102.5°; November 19, 8.30 a. m., 102°; 2.30 p. m., 105°; November 20, 8.30 a. m., 104.6°; 4 p. m., 103.8°; November 21, 10 a. m., 103°. The animal remained in good health.

REMARKS.—It is evident that this culture fluid has lost the virulent properties which it possessed in October.

The experiments thus far detailed seem rather to relate to a study of septicæmia than of malarial poisoning. Let us now see if evidence more favorable to the conclusions of Klebs and Tommasi-Crudeli can be deduced from the following experiments, in which a fatal result did not follow the injections made.

The oscillations of temperature in these cases will, for convenience of study, be shown graphically (see Plate IV).

### *Experiment No.* 5.

*Rabbit No.* 5.—A half-grown animal, weighing 320 grams.

*September* 29.—Injected 0.75$^{cc}$ of gelatine culture solution No. 6–2, containing bacteria shown in Fig. 1, Plate II (*B. lineola?*). On the morning of October 5 a second injection was made of 1.26$^{cc}$ of the gelatine solution from culture experiment below described. On the morning of September 21 one fluid drachm of fresh gelatine solution was placed in a 2-ounce bottle; and by means of a water aspirator, which was placed upon the sidewalk in front of my laboratory, twenty gallons of air were projected through a small orifice against the surface of the gelatine solution. The following day a microscopical examination with Zeiss's one-twelfth-inch objective demonstrated the presence in this fluid of amorphous vegetable *debris*, some cells of 2–3 $\mu$ in diameter, spores of bacilli (?) solitary, in pairs and in groups, and a few motionless rods, one seen with a spore at the extremity. September 23.—*B. termo* and bacilli having a spore at each extremity, resembling the *Bacillus malariæ* of Klebs and Tommasi-Crudeli. September 24.—The same as above and radiating masses of rods and spores. September 28.—Same as previously described. October 5.—Contains vibrios, bacilli, micrococci, and rod-bacteria of many shapes and sizes. At this date 1.26$^{cc}$ of this fluid was injected into the cellular tissue of rabbit No. 5, as indicated by the perpendicular line in the temperature chart.

It will be seen that this chart taken as a whole represents a remittent or intermittent fever of very irregular character. The first portion of the curve representing the period between the dates of the first and second injections, shows an initial fever lasting two days, followed by a period of depression below the normal of nearly two days' duration, a second rise to a point 1° above the normal, followed by a second fall to 1° below on the following day. If we refer to charts 8, 10, 11, 16, and 17 on the same plate, we shall see that something like this occurred in each of these cases. We have an initial fever immediately following the injection, a period of depression below the normal, and a subsequent fever of remittent character, in which there is a certain tendency to a daily remission in the morning, followed by an exacerbation of fever usually occurring in the middle of the day. I call attention in the first place to the resemblance of these temperature charts to those of yellow fever, in which we have also an initial fever of a single paroxysm, followed by a depression below the normal, and a subsequent reactionary fever of remittent character. I attribute this resemblance to the fact that both diseases are the result of septic poisoning, although presumably of a different kind. And the remittent character of this fever, which is shown to a greater or less degree in the different charts to which attention is called, cannot, I believe, be fairly compared with the paroxysmal remittent and intermittent fevers in man, due to the widely diffused malarial poison. In the first place the remittent character, which is best shown in charts 10 and 11, is for the most part confined within limits ranging only a little more than a degree above or below the normal. In the second place the depression occurs during the night and early morning, when the external temperature is the lowest, and the exacerbation during the middle of the day, when the external heat is greatest. From observations upon healthy rabbits I am led to believe that such diurnal variations within a somewhat more restricted range are rather the rule than the exception; and in a sensitive animal suffering from any injury likely to cause fever, and especially from septicæmia, these fluctuations of temperature in response to external conditions are not surprising, and would rather be looked for than otherwise. I therefore look upon this as an irritative fever, the result of septic poisoning, rather than as evidence that some special organism capable of producing malarial fever in rabbits has been injected along with the septic organisms, which have evidently been present in all of my culture fluids.

In chart No. 6 it will be noticed that the curve differs from those we have just analyzed; in that the temperature did not at any time fall below the normal, and that a continued fever, which reached the highest point recorded in any case (107.5°) on the sixth day, finally resulted in death on the twelfth day. In this case the fluid injected was putrid urine, which had been inoculated two days previously with a minute drop of putrid meat-juice containing *B. termo*.

The following is a history of the case:

### *Experiment No.* 6.

*Rabbit No.* 6.—Half-grown animal of the same litter as Nos. 4, 5, and 7; weight, 390 grams. Injected 0.75$^{cc}$ of urine into cellular tissue of right side at 12 m.

*September* 29.—The animal became thin and feeble several days before death, which occurred October 11, and had a mucous diarrhœa. The discharges were found to contain a great variety of bacteria, among others some resembling the *B. malariæ* of Klebs and Tommasi-Crudeli. A little encysted cheesy matter was found at points of injection. The spleen weighed 0.39 grams and the liver 2.07 grams. On the 15th a culture cell, containing blood taken from the auricle of this animal, was examined with Zeiss's one-twelfth inch objective, and no organisms were discovered. Another culture cell, containing a drop of boiled urine and a little spleen pulp, collected with care from interior of organ, was found to contain numerous micrococci in pairs, chains, and zoogloœa masses.

### *Experiment No.* 8.

*Rabbit No.* 8.—Large male; weight, 1,922 grams. Injected 1.25$^{cc}$ of gelatine culture fluid No. 1 (from artificial marsh No. 1) at 8 a. m., September 30. A second injection (experiment No. 10) of 1.26$^{cc}$ gelatine culture No. 2 was made at 10 a. m. October 7. A third injection of 2$^{cc}$ of same solution injected at two points (1$^{cc}$ in each) at 1.30 p. m., October 18 (*experiment No.* 19).

It will be seen by referring to the temperature chart (No. 8, Plate IV) that a paroxysm of fever followed each injection, but that no evidence of a remittent or intermittent character was exhibited, except after the second injection. The record for eight days following this injection might be supposed to sustain the hypothesis that the fever was of a malarial nature, if supported by a sufficient amount of trustworthy evidence of the same kind. Unfortunately a study of the temperature charts of other rabbits made the subject of experiment, including my own and those operated upon by Klebs and Tommasi-Crudeli, gives but little support to this hypothesis. This fragmentary evidence, which is open to the criticism already made, viz, that the fluctuations may be due to the diurnal variations in the external temperature, can hardly be relied upon for establishing a diagnosis of malarial fever. It should be noted that the injections in the case of this rabbit produced in every instance a circumscribed abscess. One or two of these abscesses, after a considerable time, pointed externally.

### *Experiment No.* 11.

*Rabbit No.* 10.—Adult male, weight 1,534 grams.

*October* 8, 12 *m.*—Injected into cellular tissue of flank 1.35$^{cc}$ of gelatine culture No. 2. No abscess followed this injection, so that the case may be considered an uncomplicated one. The temperature chart is believed to represent a non-fatal case of septicæmia, and calls for no special remark beyond what has already been said.

### *Experiment No.* 28.

On the 28th of October this rabbit, being apparently in good health, received an injection of 1.3$^{cc}$ of spleen culture No. 4, the bacilli and other organisms already described being stirred up from the bottom before filling the syringe. A sharp paroxysm of fever followed this injection, but temperature observations were not made after the third day. The animal remained in apparent good health, and on the 12th of November was used for another experiment already detailed.

### *Experiment No.* 12.

*Rabbit No.* 11.—Adult female, weight 1,410 grams.

*October* 7, 12 *m.*—Injected 1.35$^{cc}$ of spleen culture No. 1 into cellular tissue of right flank. An abscess formed at point of injection which discharged itself at the centre of the belly. The temperature curve, shown in Chart 11, Plate IV, calls for no special remark.

### *Experiment No.* 26.

On the 29th of October a second injection of 1.26$^{cc}$ of spleen culture No. 4 was thrown into the cellular tissue of right flank of rabbit No. 11. In this case care was taken not to disturb the organisms deposited at the bottom of the beaker, only the transparent supernatant fluid being used for the injection. The result was not very different from that obtained in the case of rabbit No. 10, in which the organisms were stirred up from the bottom before filling the syringe. In neither case did any noticeable result follow, beyond the temporary paroxysm of fever immediately following the injection.

### *Experiment No.* 17.

*Rabbit No.* 16.—Weight 1,596 grams.

*October* 13, 10 *a. m.*—Injected into subcutaneous connective tissue of left flank 2$^{cc}$ of culture fluid No. 6-2 (containing bacteria, shown in Fig. 1, Plate II.) The temperature curve is shown in Chart 16, Plate IV. In this case the initial fever produced by the injection, and immediately following it, was higher than in any other instance. Attention is especially called to the remarkable resemblance of this chart to that of many cases of yellow fever.

### *Experiment No.* 21.

*Rabbit No.* 17.—Adult male, weight 62¼ oz.

*October* 18, 2 *p. m.*—Injected 1.26$^{cc}$ of gelatine solution from culture experiment No. 4, containing numerous filaments (see Fig. 8, Plate 2), and vibrios (see Fig. 4, Plate II).

The temperature curve is shown in Chart 17, Plate IV, and calls for no special remark.

*Tabular statement of injection experiments upon rabbits.*

| Experiment. | Rabbit. | Date of injection. | Nature and amount of material injected. | Result. | Weight of rabbit in grammes. | Weight of spleen, in grammes. | Proportion. | Reference to text. |
|---|---|---|---|---|---|---|---|---|
| *No.* | *No.* | 1880. | | | | | | |
| 1 | 1 | May 12 | 5 c. c. of distilled water, containing organisms from surface of swamp mud. | Negative | | | | See page 3. |
| 2 | 2 | May 16 | 5 c. c. of distilled water, containing particles from 30 gallons of air (vicinity of swamp). | do | | | | See page 3. |
| 3 | 3 | May 22 | 5 c. c. of Cohns fluid, containing bacteria | do | | | | See page 3. |
| 4 | 4 | Sept. 29 | 0.75 c. c. of gelatine culture solution No. 1 | Died October 1 | 474 | .82 | $\frac{1}{578}$ | See page 5. |
| 5 | 5 | Sept. 29 | 0.75 c. c. of gelatine solution No. 6-2 | Fever not fatal | 320 | | | See page 8. |
| 6 | 6 | Sept. 29 | 0.75 c. c. of urine, containing bacteria of putrefaction | Died October 11 | 390 and 493 | .39 | $\frac{1}{1000}$ | See page 6. |
| 7 | 7 | Sept. 29 | 0.50 c. c. of saliva (Dr. S.) | Died October 2 | 304 | .45 | $\frac{1}{675}$ | See page 5. |
| 8 | 8 | Sept. 30 | 1.26 c. c. of gelatine culture solution No. 1 | Fever not fatal | 1922 | | | See page 8. |
| 9 | 9 | Oct. 3 | 1.26 c. c. of water shaken up with surface mud from swamp | Died October 7 | 1089 and 1534 | .51 | $\frac{1}{2137}$ | See page 6. |
| 10 | 8 | Oct. 7 | 1.35 c. c. of swamp culture No. 2 (gelatine solution) | Fever not fatal | | | | See page —. |
| 11 | 10 | Oct. 7 | 1.35 c. c. of swamp culture No. 2 (same as above) | do | | | | See page 9. |
| 12 | 11 | Oct. 7 | 1.35 c. c. of spleen culture No. 1 | do | | | | See page 9. |
| 13 | 12 | Oct. 7 | 1.35 c. c. of water from gutter mud | Died October 10 | | | | See page 6. |
| 14 | 13 | Oct. 15 | 2 c. c. of spleen culture No. 1 | Died October 17 | 1088 | .39 | $\frac{1}{2790}$ | See page 6. |
| 15 | 14 | Oct. 15 | 2 c. c. of swamp culture No. 2 (gelatine solution) | October 19 | 1057 | .39 | $\frac{1}{2710}$ | See page —. |
| 16 | 15 | Oct. 15 | 1.5 c. c. of pus culture No. 1 | October 16 | 1959 | .78 | $\frac{1}{2511}$ | See page 6. |
| 17 | 16 | Oct. 15 | 2 c. c. gelatine culture No. 6-2 | Fever not fatal | | | | See page 9. |
| 18 | 17 | Oct. 15 | 2 c. c. gelatine solution from stock bottle, containing *Penicillium* | Slight fever | | | | See page 7. |
| 19 | 8 | Oct. 18 | 2.5 c. c. of swamp culture No. 2. (gelatine solution) | Fever not fatal | | | | See page 6. |
| 20 | 18 | Oct. 18 | 2 c. c. of water from swamp mud | Death October 20 | | | | |
| 21 | 17 | Oct. 18 | 1.26 c. c. gelatine culture No. 4 | Fever not fatal | | | | See page 9. |
| 22 | 16 | Oct. 24 | 1.26 c. c. filtered liquid from gelatine culture No. 6-2 | Slight fever | | | | See page —. |
| 23 | 17 | Oct. 24 | 1 c. c. of unfiltered remnant of above liquid | Fever not fatal | | | | See page —. |
| 24 | 8 | Oct. 25 | 1.26 c. c. washings of *Spirogyra*, etc | Slight fever; not fatal | | | | See page 7. |
| 25 | 10 | Oct. 25 | 1 c. c. of bruised *Spirogyra*, etc | do | | | | See page 7. |
| 26 | 11 | Oct. 27 | 1.26. c. c. of spleen culture No. 4. (supernatant liquid) | Fever not fatal | | | | See page 9. |
| 27 | 11 | Oct. 28 | The above injection repeated | do | | | | See page —. |
| 28 | 10 | Oct. 28 | 1.3 c. c. of spleen culture No. 4 (stirred up from bottom) | do | | | | See page 9. |
| 29 | 5 | Nov. 4 | 1.26 c. c. of water, containing surface mud from gutter, filtered | do | | | | See page 7. |
| 30 | 8 | Nov. 4 | 1.26 c. c. of same solution as above, not filtered | Died November 9 | 1912 | .78 | $\frac{1}{2451}$ | See page 7. |
| 31 | 10 | Nov. 12 | 1.26 c. c. of saliva (Dr. S.) | Fever not fatal | | | | See page 7. |
| 32 | 11 | Nov. 12 | do | Slight fever | | | | See page 7. |
| 33 | 16 | Nov. 12 | 1 c. c. of pus culture No. 6 | Fever not fatal | | | | See page 8. |
| 34 | 19 | Nov. 18 | 1.26 c. c. of water, containing surface mud from gutter | Died November 22 | | | | See page 8. |
| 35 | 20 | Nov. 18 | 2 c. c. of saliva (Dr. S.) | Died November 20 | 2178 | 1.81 | $\frac{1}{1203}$ | See page 7. |
| 36 | 21 | Nov. 18 | 0.5 c. c. of spleen culture No. 4 | | | | | |
| 37 | 22 | Nov. 18 | 0.5 c. c. of pus culture No. 6 | Fever not fatal | | | | See page 8. |

### CONCLUSIONS.

A great number of minute algæ, including bacteria of various forms, are found upon the surface of swamp-mud in the vicinity of New Orleans, and also in the gutters within the city limits.

Many of these forms may be successfully cultivated in fish gelatine solution (method of Klebs), and this fluid, previously innocuous, acquires pathogenic properties as the result of inoculation with these organisms.

It is evident that the pathogenic properties acquired by gelatine solution and other organic liquids after inoculation with bacterial organisms is due, directly or indirectly, to the presence of these bacteria, for, if they are excluded, such fluid may be kept indefinitely without undergoing change, and are innocuous when injected beneath the skin of a rabbit.

Some of the organisms found in swamp mud, in gutter-water, and in human saliva are capable of multiplying within the body of a living rabbit, and the fluids and organs containing them (blood, serum from cellular tissue, spleen, &c.), possess virulent properties. In other words, an infectious disease is produced which may be transmitted from animal to animal by inoculation.

Among the organisms found upon the surface of swamp-mud, near New Orleans, and in the gutters within the city limits are some which closely resemble and, perhaps, are identical with the *Bacillus malariæ* of Klebs and Tommasi-Crudeli; but there is no satisfactory evidence that these, or any other of the bacterial organisms found in such situations, when injected beneath the skin of a rabbit, give rise to a malarial fever corresponding with the ordinary paludal fevers to which man is subject.

The evidence upon which Klebs and Tommasi-Crudeli have based their claim of the discovery of a *Bacillus malariæ* cannot be accepted as sufficient; (*a*) because in their experiments and in my own the temperature curve in the rabbits operated upon has in no case exhibited a marked and distinctive paroxysmal character; (*b*) because healthy rabbits sometimes exhibit diurnal variations of temperature (resulting apparently from changes in the external temperature,) as marked as those shown in their charts; (*c*) because changes in the spleen such as they describe are not evidence of death from malarial fever, inasmuch as similar changes occur in the spleens of rabbits dead from septicæmia produced by the sub-cutaneous injection of human saliva;[*] (*d*) because the presence of dark-colored pigment in the spleen cannot be taken as evidence of death from malarial fever, inasmuch as this is frequently found in the spleen of septicæmic rabbits (*l. c.*).

While, however, the evidence upon which Klebs and Tommasi-Crudeli have based their claim to a discovery is not satisfactory and their conclusions are shown not to be well founded there is nothing in my researches to indicate that the so-called *Bacillus malariæ*, or some other of the minute organisms associated with it, is not the active agent in the causation of malarial fevers in man. On the other hand there are many circumstances in favor of the hypothesis that the etiology of these fevers is connected, directly or indirectly, with the presence of these organisms or their germs in the air and water of malarial localities.

The truth or falsity of this hypothesis can only be settled by extended experimental investigations, and while further experiments upon animals may lead to more definite results it seems probable that the *experimentum crucis* must be made upon man himself.

In a disease not of a fatal character and one for which we have a prompt and reliable remedy, it would seem that subjects for experiment might be found, especially among medical men and medical students, who have always shown themselves ready to subject themselves to inconvenience or even to danger in the pursuit of scientific discoveries of value to mankind.

The method of conducting such experiments which seems to me to promise the best results is the isolation and cultivation of the various organisms found in malarial localities which may possibly be concerned in the production of malaria, a careful study of the life-histories of these organisms, and an experimental investigation of the physiological action of each when taken into the stomach, or respired in a dry state, by healthy individuals. Such a study, to be of value, will necessarily involve a considerable expenditure of time and money, and requires that the experimenters shall be familiar with the most approved methods of making culture-experiments and with the technique of microscopical manipulations with high powers, improved illuminating apparatus, &c.

Another method worthy of trial in connection with this would be to carefully study the bacterial organisms found in the mouth and alimentary canal of persons suffering from malarial fevers[†] as compared with the common forms constantly found in the same situations in healthy individuals, with reference to the determination of the presence of unusual forms or of an abnormal abundance of common forms, or of possible physiological varieties of these forms not possessing morphological peculiarities.

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[*] This statement is based upon observations made subsequently to those recorded in this report. (See special report to National Board of Health. "A fatal form of septicæmie in the rabbit, produced by the subcutaneous injection of human saliva."—*Bulletin, No.* 44, *April* 30, 1881.)

[†] I do not refer to an examination of the blood, as a careful search in a considerable number of cases

Finally, I may say that I entered upon this investigation without prejudice, but hoping that I might be able to confirm the conclusions of Klebs and Tommasi-Crudeli, whose researches were evidently prompted by a truly scientific spirit, and were conducted in accordance with strictly scientific methods. I believe that their work will prove useful in many ways to future explorers in this field, and have an abiding faith that light will eventually be shed upon this and similar problems by the persistent and intelligent application of the experimental method supported by all the resources of modern science.

Before concluding this report I desire to express my obligations to Dr. Gustav Devron, of New Orleans, for numerous favors and for assistance rendered during the prosecution of this investigation; and to Dr. John Dell' Orto, of New Orleans, for a translation of the memoir of Klebs and Tommasi-Crudeli, a labor which he voluntarily undertook in the midst of active professional work, and for which he has my sincere hanks.

## DESCRIPTION OF PLATES.

### PLATE I.

*Figs.* 1, 2, *and* 3.—The *Bacillus malariæ* of Klebs and Tommasi-Crudeli; reproduced by photography and the heliotype process from their figures. (See their mémoir Studi sulla Natura della Malaria, Roma, 1879.) The figures are reduced to about four-fifths the original size. (See p. 2, for description of the *Bacillus malariæ*.)

*Fig.* 4.—Bacteria from surface of *bouillon*, exposed in biological laboratory, Johns Hopkins University, Baltimore, Md., May, 1881. × 1,000 diameters by Zeiss's one-eighteenth objective.

*Fig.* 5.—Minute filamentous algæ, Oscillatorieæ and Leptothrix, from gutter-water New Orleans; common and widely distributed species. × 180 diameters.

*Fig.* 6.—Bacilli in leptothrix chains, resembling Klebs and Tommasi-Crudeli's Fig. 1, from surface of *bouillon* exposed in laboratory, Baltimore, Md. × 1,000 diameters by Zeiss's one-eighteenth-inch objective.

*Fig.* 7.—Protococcus (changed in appearance by iodine staining), and minute bacilli from surface of glass-slide exposed over swamp mud—"artificial marsh"—in laboratory, New Orleans, September, 1880. Some of these bacilli presented the appearance of having spores at each extremity like those figured by Klebs and Tommasi-Crudeli. × 1,000 diameters by Zeiss's one-eighteenth-inch objective.

*Fig.* 8.—Minute alga (Leptothrix), from surface of swamp mud near New Orleans, September, 1880. Common also in gutter-water. × 1,000 diameters by Zeiss's one-eighteenth-inch objective.

*Fig.* 9.—The same alga, apparently, as that shown in last figure, from diarrhœal discharges of Dr. S. while in New Orleans, September, 1880. This form was quite abundant and was observed on several occasions. With the exception of a slight diarrhœa, the subject was in good health at the time. × 1,000 diameters by Zeiss's one-eighteenth-inch objective.

### PLATE II.

*Fig.* 1.—Mycoderma (*Bacterium lineola ?*) from surface of fish-gelatine solution, culture No. 6 (see page 4,) inoculated with mud from bank of Mississippi River, New Orleans, September, 1880. × 1,500 diameters by Zeiss's one-eighteenth-inch hom. oil im. objective.

*Fig.* 2.—Bacteria from surface of fish-gelatine solution inoculated with swamp mud (see page 5), culture experiment *à la* Klebs and Tommasi. × 1,500 diameters by Zeiss's one-eighteenth-inch objective. New Orleans, September, 1880.

*Fig.* 3.—The same as Fig. 2 from bottom of gelatine culture—solution, showing spores (?) at each extremity and sometimes a central spore like those described by Klebs and Tommasi-Crudeli. × 1,500 diameters by Zeiss's one-eighteenth-inch objective. This and the preceding figure are from preparations stained with sulphuric acid and iodine solution. (See account of method in Monthly Microscopical Journal, April, 1881.)

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with a Zeiss's one-eighteenth-inch objective has failed to demonstrate the presence of any organisms in the blood of patients suffering from pronounced malarial fever. The absence of "germs" from the blood does not, however, settle the question against the supposition that these fevers are parasitic germ diseases, as the pathogenic organism may find a congenial habitat in the alimentary canal, in the lymphatics, or elsewhere, and may not thrive in the blood-stream itself. In the fatal form of septicæmia which I have recently investigated the micrococcus multiplies abundantly in the sub-cutaneous connective tissue from the moment that it is introduced by injection, but it does not enter the blood until the case is near a fatal termination. Pasteur has found the same to be the case in a form of septicæmia studied by him in which the pathogenic organism is a long and slender vibrio.

*Fig.* 4.—Vibrios in gelatine solution (culture experiment), New Orleans, September, 1880. × 1,000 diameters by Zeiss's one-eighteenth-inch objective.

*Fig.* 5.—Encysted amœbæ and vegetable organisms developed in fish-gelatine solution (culture experiment). (See page 4.) New Orleans, September, 1880. × 1,000 diameters by Zeiss's one-eighteenth-inch objective.

*Fig.* 6.—*Protococcus* from surface of glass slides exposed over swamp mud—"artificial marsh." Common form in and about New Orleans. × 400 diameters by Beck's one-fifth-inch objective.

*Fig.* 7.—Masses of flexible filaments found in abundance at bottom of fish-gelatine solution; culture experiment *à la* Klebs and Tommasi-Crudeli. (See page 4.) New Orleans, September, 1881. × 1,425 diameters.

*Fig*, 8.—Same as Fig. 7. × 1,000 diameters. Iodine staining.

*Fig.* 9.—Bacilli (*B. subtilis?*) with spores at one extremity from culture cell containing serum from cellular tissue of septicæmic rabbit. × 650 diameters by Zeiss's one-twelfth inch objective. This form was frequently found in culture fluids exposed in my laboratory in New Orleans, and also in abundance in the fish-gelatine culture experiments.

### PLATE III.

Temperature charts of rabbits reproduced from the memoir of Klebs and Tommasi-Crudeli. The scale has been changed from Centigrade to Fahrenheit for the convenience of American readers. In this and the following plate the horizontal lines indicate degrees of temperature, and the normal temperature of the rabbit (about $103^{C}$) is indicated by a heavier line. The perpendicular lines indicate days.

*No.* 1.—This rabbit received (April 16, 1879) an injection of $1.6^{cc}$ of water "which had been drawn three days previously from the mud of Caprolace."

*No.* 2.—Received (April 16, 1879) an injection—subcutaneous—of $0.6^{cc}$ of fish-gelatine solution inoculated April 11 with mud from Caprolace.

*No.* 3. Received (April 25) subcutaneous injection of $3^{cc}$ of water which had remained for a long time on the mud of Caprolace.

*No.* 4. Received (April 25) subcutaneous injection of $1.6^{cc}$ of fish-gelatine solution inoculated two days previously with mud of Caprolace.

*No.* 5.—Received (May 2) subcutaneous injection of $3.2^{cc}$ of fish-gelatine solution inoculated some time previously with mud of Caprolace.

*No.* 13.—Received (May 14) a subcutaneous injection of $6.4^{cc}$ of culture liquid inoculated with earth from the "aquitano of the hill."

*No.* 15.—Received $6.4^{cc}$ of water shaken up with earth from Valehetta and filtered.

### PLATE IV.

Temperature charts of rabbits; Dr. Sternberg's experiments in New Orleans, September, October, and November, 1880. The heavy perpendicular dash indicates the date of an injection.

*No.* 5.—Received, September 29, a subcutaneous injection of $0.75^{cc}$ of gelatine culture solution No. 6–2 (see p. 8,) and on October 5 a second injection of $1.26^{cc}$ of gelatine-culture solution through which air had been passed by means of aspirator (see p. 8.)

*No.* 6.—Received, September 29, a subcutaneous injection of putrid urine, containing *B. termo.* Died October 11.

*No.* 8.—Received, September 30, a subcutaneous injection of fish-gelatine culture solution No. 1 (from artificial marsh No. 1.) A second injection of $1.25^{cc}$ gelatine culture No. 2, was made October 7, and a third injection of $2^{cc}$ of the same liquid on October 18.

*No.* 10.—Received, October 8, a subcutaneous injection of $1.35^{cc}$ gelatine culture No. 2 (inoculated with mud from swamp), and on October 28, a second injection of spleen culture No. 4.

*No.* 11.—Received, October 7, a subcutaneous injection of $1.35^{cc}$ of spleen culture No. 1 (see p. 6), and on October 27, a second injection of $1.26^{cc}$ of spleen culture No. 4.

*No.* 16.—Received, October 15, a subcutaneous injection of $2^{cc}$ of culture fluid No. 6–2 (see p. 6), and on October 24 $1.26o^{cc}$ of filtered liquid from gelatine culture No. 6–2. On November 4 a third injection of $1^{cc}$ of pus culture No. 6 was made.

*No.* 17.—Received, October 15, a subcutaneous injection of $2^{cc}$ gelatine solution from stockbottle containing *Penicillium;* on October 18 a second injection of $1.26^{cc}$ of gelatine culture No. 4; and on October 24 a third injection of $1^{cc}$ of gelatine culture solution No. 6–2.

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PLATE I.

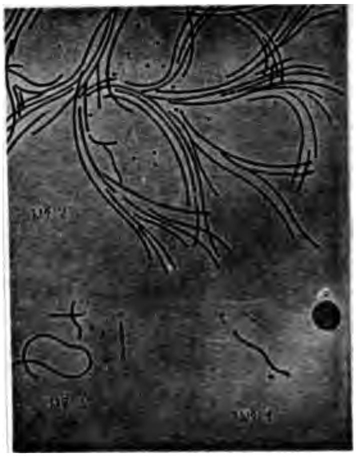

Fig. 3.

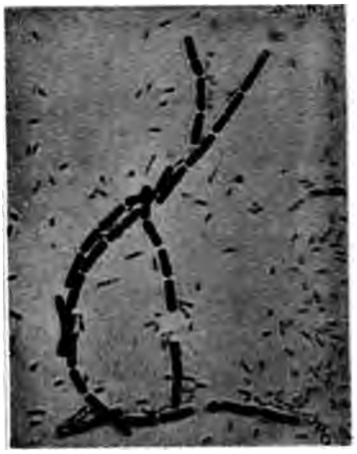

Fig. 6.

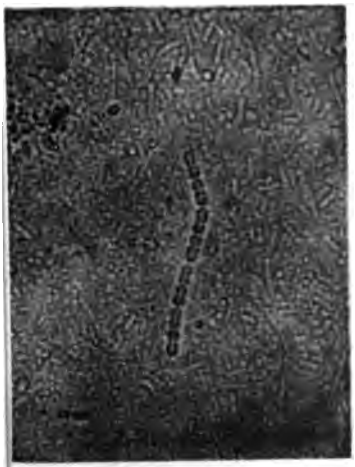

Fig. 9.

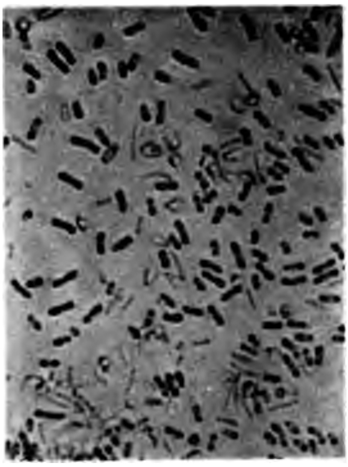

Fig. 3.

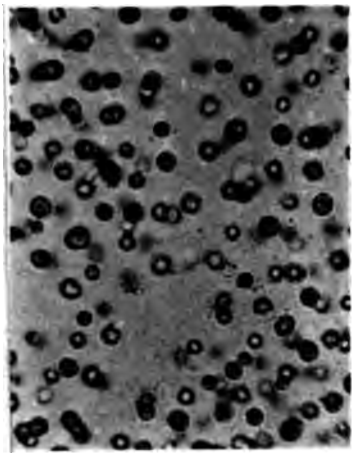

Fig. 6.

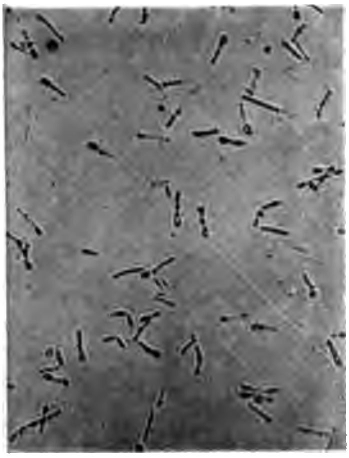

Fig. 9.

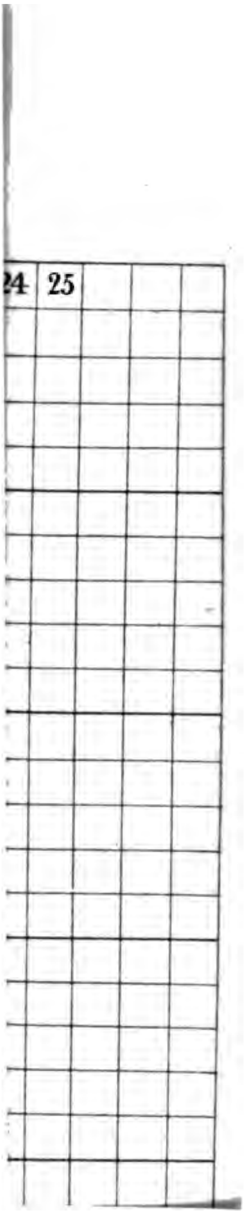

Fig. 9.

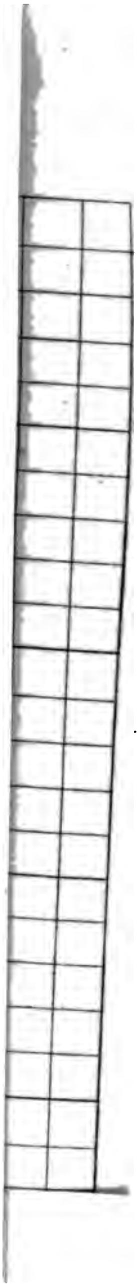

Fig. 9.

# *A FATAL FORM OF SEPTICÆMIA IN THE RABBIT, PRODUCED BY THE SUBCUTANEOUS INJECTION OF HUMAN SALIVA.*

## AN EXPERIMENTAL RESEARCH.

By GEO. M. STERNBERG, *Surgeon U. S. A.*

In a report made to the National Board of Health in February last, I have given a detailed account of certain experiments, made in the first instance as a check upon experiments relating to the so-called *Bacillus maliariæ* of Klebs and Tommasi-Crudeli, which show that my own saliva has remarkable virulent properties when injected into the subcutaneous connective tissue of a rabbit. Further experiments made in the biological laboratory of the Johns Hopkins University have fully confirmed the results heretofore obtained, and the object of the present report is to place upon record these last experiments, which are of special interest just now because of the announcement by Pasteur of "*a new disease,*" produced in rabbits by the subcutaneous injection of the saliva of an infant which died of hydrophobia in one of the hospitals of Paris. (Comptes Rendus Ac. d. sc. 1881, xcii, page 159.)

I have demonstrated by repeated experiments that my saliva in doses of 1.25 c. c.$^3$ to 1.75 c. c$^3$. (see note 1) injected into the subcutaneous connective tissue of a rabbit, infallibly produces death within forty-eight hours.

I have commonly injected an amount varying from 5 to 25 minims, according to the size of the animal, but in small rabbits have had a fatal result in three cases out of five follow the injection of 1 minim diluted with 5 minims of water.

Query. Do similar results follow the injection of other fluids containing organic matter in suspension or solution?

Answer. One c. c$^3$. of my own blood failed to kill a rabbit; 1 c. c$^3$. of putrid urine containing *B. termo* in abundance failed to kill a small rabbit; 1 c. c$^3$. (each) of liquid fœces and distilled water (1 to 10) failed to kill two rabbits; 1.25 c. c$^3$. of bouillon undergoing putrefaction and loaded with *B. termo* failed to kill a rabbit; 1 c. c$^3$. of sediment from Baltimore water, consisting of organic *debris* and organisms—chiefly *Bacillus subtilis Leptothrix pusilla, Protococcus,* and a few diatoms and flagellate monads—failed (note 1) to kill a rabbit.

On the other hand, injections of a small quantity of surface mud from the gutters of New Orleans during the month of September, 1880, invariably produced fatal results within forty-eight hours. (See unpublished report above referred to.)

NOTE 1.—Coze and Feltz found as the result of numerous experiments that the blood of healthy persons and that of sick with non-infectious maladies does not produce fatal results when injected into the subcutaneous tissues of rabbits (Clinical and Exp. Researches upon Infectious Maladies, 8°, Paris, 1872). Pasteur also has inoculated, without result, the saliva of asphyxiated rabbits and of men dead with common diseases (*l. c.*).

Query. Does the saliva of other individuals injected in the same manner produce similar results?

Answer. The saliva of four students, residents of Baltimore (in March), gave negative results; eleven rabbits injected with the saliva of six individuals in Philadelphia (in January) gave eight deaths and three negative results; but in the fatal cases a less degree of virulence was shown in six cases by a more prolonged period between the date of injection and the date of death. This was three days in one, four days in four, and seven days in one.

Query. Is there any recognizable peculiarity in the saliva which exhibits the greatest degree of virulence?

Answer. In the case of Dr. S., whose saliva shows an exceptional virulence, the teeth are sound, the secretions of the mouth normal in physical properties and reaction, and the general health good. There is perhaps an unusual flow of saliva, but no other noticeable peculiarity.

Query. Is there any plausible hypothesis by which the difference in virulence can be explained?

Answer. This question will require for its solution more extended experiments. In the meantime it may be mentioned, as having a possible bearing upon the subject, that Dr. S. has been engaged to a considerable extent, during the past two years, in studies which have brought him in contact with septic material. Dr. F., of Philadelphia, whose saliva killed (after a long interval) two rabbits, is pathologist to a large hospital, and consequently is constantly brought in contact with septic material. Mr. N. and Mr. B., whose saliva killed all the rabbits operated upon (four), are residents of seaport towns in Cuba. (See Note 2.)

NOTE 2.—The possibility that this septic condition of the secretions of the mouth may bear some relation to the protection which these Cubans and myself enjoy against yellow fever, which is a disease presenting many points of resemblance to septicæmia, has occurred to me, and without at present laying any great stress upon this possibility, I think it worthy of further experimental consideration.

Query. Is death produced in other animals by the subcutaneous injection of human saliva which is virulent for rabbits?

Answer. Injection of $4^{cc}$ into each of two small dogs produced local abscesses at point of injection, but no other noticeable result. (See Note 3.) Injection of 0.25 to $^{cc}$ into five chickens produced no result. Injection of $0.75^{cc}$ (each) into three guinea-pigs proved fatal to two, one in three and one in seven days. Injection of $0.5^{cc}$ into five rats resulted fatally to one only. (See Note 4.)

NOTE 3.—A dog succumbed, however, to an injection of $1^{cm^3}$ of serum from the subcutaneous cellular tissue of a rabbit recently dead.

NOTE 4.—The results obtained by me in these experiments correspond with those reported by Pasteur in the paper already referred to, viz. guinea-pig less susceptible than rabbit, complete immunity of the chickens, and susceptibility of the dog to the "new disease," as the result of injections of blood from dead rabbits.

Query. What is the nature of the fatal malady produced in rabbits by the subcutaneous injection of the saliva of certain individuals?

Answer. The course of the disease and the post-mortem appearance indicate that it is a form of *septicæmia*. Immediately after the injection there is a rise of temperature, which in a few hours may reach 2° to 3° centigrade (3.6° to 5.4° Fahrenheit); the temperature subsequently falls, and shortly before death is often several degrees below the normal. There is loss of appetite and marked debility after twenty-four hours, and the animal commonly dies during the second night or early in the morning of the second day after the injection. Death results still more quickly when the blood, &c., from a rabbit recently dead is injected. Not unfrequently convulsions immediately precede death. The date and mode of death correspond with that reported by Pasteur in the memoir referred to. Two rabbits injected with buccalmucus from the mouth of a child recently dead with hydrophobia, December 11, were found dead December 13. Other rabbits inoculated with the blood and saliva of these died in still less time. Inoculation with fresh blood usually produced death in less than twenty-four hours. The most marked pathological appearance is a diffuse inflammatory œdema or cellulitis extending in all directions from the point of injection, but especially to the dependent portions of the body.

Occasionally there is a little pus near the puncture, but usually death occurs before the cellulitis reaches the point of producing pus. The subcutaneous connective tissue contains a quantity of bloody serum, which possesses virulent properties, and which contains a multitude of micrococci. There is usually more or less inflammatory adhesion of the integument to the subjacent tissues. The liver is sometimes dark-colored and gorged with blood, but more frequently is of a lighter color than normal and contains much fat. The spleen is either normal in appearance or enlarged and dark-colored. Changes in this organ are more marked in those cases which are of the longest duration.

In certain cases dark-colored pigment has been found in the spleen resembling that which has been supposed to be characteristic of malarial fever. The blood is dark-colored, usually fluid, and there is a tendency to agglutination of the red corpuscles. The blood commonly contains an immense number of micrococci, usually joined in pairs and having a diameter of about 0.5 W. These are found in blood drawn from superficial veins, from arteries, and from cavities of the heart immediately after death, and in a few cases their presence has been verified during life; observations thus far made indicate, however, that it is only during the last hours of life that these parasites multiply in the circulating fluid, and in a certain proportion of the cases a careful search has failed to reveal their presence in post-mortem examinations made immediately upon the death of the animal. This organism, however, is invariably found in great abundance in the serum which exudes in considerable quantities from the œdematous connective tissue when an incision is made through the integument over any point involved in the inflammatory œdema extending from the original puncture. A perusal of the paper of Pasteur, already referred to, has induced me to pay special attention in three recent post-mortems to some points to which this author refers, which I had not noticed in previous examinations, viz, to the condition of the trachea, the lungs, and the lymphatic glands in the groins and axillæ.

Pasteur says: "The cellular tissue is almost always emphysematous. (This has not been observed to be the case, except to a slight extent in one instance, in the rabbits operated upon by me.) The lungs are frequently filled with *noyaux* of pulmonary apoplexy. (I have found this to be case in one out of three rabbits examined since my attention has been directed to this point.) 'A character more constant than the last (not more constant, however, than that which relates to the volume and color of the *ganglions*) is the state of the trachea, which is almost invariably red, congested, with little hemorrhages from the smallest vessels.'" (I have found a marked congestion of the vessels of the trachea, in the three cases in which I have examined it, and in one case the lymphatic glands of the axillæ were enlarged and congested.)

Query. What constituent of the saliva injected produces the fatal malady in question?

Answer. The following facts demonstrate that *the phenomena detailed result from the*

***presence of a living organism found in the saliva—a micrococcus—which multiplies abundantly in the subcutaneous connective tissue, and also in the blood shortly before or after death.***

(*a.*) ***The poison is particulate.*** This is proved by numerous filtration experiments. *Example:* March 15, 11 a. m., injected 1 $^{cc3}$ of filtered saliva (filtered through thin stratum of plaster of Paris by means of Sprengel's pump) into left flank of rabbit weighing one pound, and at the same time one-fourth the quantity of unfiltered saliva into a rabbit of the same size. No harm resulted to the first rabbit, while the second died the following day at 5.30 p. m.

(*b.*) *The virulence of the saliva is destroyed by boiling.*

(*c.*) *The saliva loses its virulence when kept for twenty-four hours in a culture chamber at at temperature of 37° centigrade.*

NOTE.—The presence of *B. termo* and an odor of putrefactive in saliva kept for twenty-four hours in a culture chamber shows that changes are occurring which have heretofore been recognized as destructive of the septic poison (organism); *e. g.*, the virulence of the poison which produces dangerous dissection wounds is lost when putrefaction changes set in.

(*d.*) *The addition of one part of a* 10 *per cent. solution of carbolic acid to two parts of saliva destroys its virulence.*

(*e.*) ***The effused serum from the subcutaneous connective tissue of a rabbit recently dead produces death, attended with the same phenomena as resulted from the injection of the saliva in the first instance.*** But this does not contain epithelial cells or salivary corpuscles, and we are, therefore, justified in excluding these as possible agents in the production of the results indicated. Moreover, these are present at all times in the saliva of all individuals, while virulence, at least such an intense degree of virulence, is an exceptional property of human saliva.

(*f.*) ***This serum loses its virulence by filtration.***

Unfiltered serum from a recently dead rabbit has invariably proved fatal in smaller quantity and in less time than is required by the saliva in the first instance, showing an increase of virulence as the result of successive cultivation of the organism in the body of a susceptible animal. This corresponds with the results obtained by Davaine, Koch, Pasteur, and others. I have not attempted to ascertain the minimum quantity which will produce death. Davaine says, "A rabbit may be killed by the $\frac{1}{1000}$ part of a drop of septic blood." (Bull. de l'Acad. de Med., 2 s. t. viii, p. 121.) In my filtration experiments I injected, however, quantities far in excess of the amount required to produce speedy death if unfiltered serum had been employed.

*Example:* March 14. Injected 2 cm$^3$ of filtered serum (from subcutaneous connective tissue of rabbit recently dead) diluted with distilled water (1 to 20) without result, while one-quarter of the quantity (5 cm$^3$) of the same dilution *unfiltered* injected at the same time into another rabbit produced death in twenty-four hours.

(*g.*) **The micrococcus present in the serum from the connective tissue of a rabbit which has succumbed to a subcutaneous injection of saliva may be cultivated in bouillon made from the flesh of a healthy rabbit, or in blood serum obtained from a healthy dog, and these fluids thereby acquire a virulence which they did not have before.**

My first efforts to cultivate the micrococcus in urine, in gelatine solution, and in bouillon made from the flesh of a dog, all proved ineffectual, and these fluids, after inoculation with blood or serum from the connective tissue, showed a temporary virulence only, which was doubtless due to the presence of the micrococci introduced, which preserved their vitality for a certain time, although the conditions were not favorable for their increase. After a few days the first culture lost its virulence, and successive inoculations gave negative results, both as to the presence of the micrococcus and as to noxious properties when injected into rabbits.

(*h.*) **Successive cultures in which but a small drop is taken each time to inoculate a fresh quantity of bouillon exclude the white and red blood-corpuscles (filtration experiments have already shown the poison to be particulate) as possible agents in the production of this virulence and prove conclusively that the veritable cause is the presence of a micrococcus, found first in the saliva, then in the serum from the connective tissue and (usually) in the blood of the animal killed by the injection of saliva, and finally in each successive culture fluid inoculated (in the first instance) with a small quantity of this serum or blood.** Within a few hours after inoculating sterilized bouillon made from the flesh of a rabbit (first tested for several days in a culture oven at a temperature of 37° cent.), with blood, or serum from subcutaneous connective tissue of a rabbit recently dead, the fluid—previously transparent—becomes opalescent, and upon microscopical examination is found to contain innumerable micrococci, solitary, in pairs, (Fig. 8), and in torula chains. The same result follows upon inoculating a second portion with a minute drop from the first, and so on. The continued virulence of these successive cultures I have amply proved.

*Example:* April 13. Injected 1 cm$^3$ of bouillon culture No. 6 (six successive inoculations, the first with serum from subcutaneous connective tissue of rabbit) into left flank of a large rabbit. *Result:* The animal was found dead on the morning of the 16th, and presented the usual appearances upon post-mortem examination. Its blood and the effused serum in subcutaneous connective tissue contained, as usual, an immense number of micrococci, like those already described.

*Query:* Does the micrococcus found under the circumstances detailed differ from the *Micrococcus septicus* of Cohn, and is it identical with the organism described by Pasteur, as present in the blood of rabbits killed by the subcutaneous injection of the saliva of an infant dead from hydrophobia (1. c.)?

*Answer.* Cohn describes the *M. septicus* as follows:

Little rounded cells of 0.5 $\mu$ motionless and crowded in masses or united in chaplets in the secretion of wounds in cases of septicæmia (Klebs), in *zooglœa*, in callous ulcers, in isolated cells, united *in pairs*, or in chaplets in the serum of *epidemic puerperal fever* (Waldyer) in all the tissues, vessels, &c., in cases of pyæmia and septicæmia. (The Bacteria; Magnin, Little, Brown & Co. Boston, 1880, p. 76.)

Pasteur gives the following description of the micrococcus found by him in the fatal disease described by him as new, and which he evidently does not consider identical with septicæmia, a disease which he had previously studied experimentally. It should be noticed, however, that Pasteur recognizes several forms of septicæmia. Thus he says: "And now we see why septicæmia has so often been confounded with charbon; their causes are of the same order; it is a vibrio which causes septicæmia and a bacillus which produces charbon. * * * Septicæmia and putrefaction in a living being are not the same thing. *There are as many different septicæmias as there are different vibrios.* * * * In septicæmia the vibrios do not appear in the blood until the last thing, but in this liquid one of them takes a peculiar aspect, often longer than the diameter of the field of the microscope, and so transparent that it easily escapes observation; when, however, it is once perceived it is easily found again, flexble, climbing and removing the blood-globules as a serpent moves the grass in the bushes, etc. (Charbon and septicæmia, C. R. Ac. des Sc., lxxxv, 101–115.)

This septic vibrio of Pasteur I found in the blood of rabbits, victims of my experiments, in New Orleans during the past summer, but have not since met with it; perhaps, because it develops *post mortem*, and requires the hot weather of summer for its development. Whether it is an independent organism or is developed under special conditions from the *Micrococcus septicus*, being an advanced phase in the development of this organism corresponding with the spore-producing filaments which have been shown to constitute one phase in the life history of *Bacillus anthracis* (Koch) and of *Bacterium termo* (Ewart) is an interesting question for further research. The vivid language of Pasteur describes it well, and the wonderful vigor with which this extremely slender and almost transparent organism thrusts aside the blood corpuscles in its impetuous serpentine movements cannot fail to astonish the observer.

The micrococcus of Pasteur's "new disease" is, on the contrary, quite motionless, and is described as follows:

This organism is sometimes so small that it may escape a superficial observation. Its form does not differ from that of many other microscopic beings. It is an extremely short rod a little compressed towards the middle, resembling a figure 8, and of which the diameter of each half often does not exceed a half a thousandth of a millimeter [= 0.5M and corresponding with the diameter given by Cohn for the *Micrococcus septicus*, also with the micrococcus observed by myself in the form of septicæmia described in this report]. Each of these little particles is surrounded at a certain focus with a sort of aureole, which corresponds perhaps to a material substance.

(NOTE.—The possibility that this appearance is due to diffraction is considered, but Pasteur inclines to the opinion that in the case in question it is due to a mucous substance which surrounds the organism.)

The foregoing descriptions answer as well for the micrococcus observed by me as if they had been written especially for it, and it is unnecessary for me to say more at present in relation to the morphology of this organism which apparently is identical with that of the *Micrococcus septicus* of Cohn, and with the organism found by Pasteur in the "new disease" described by him. Does it, then, follow that the organisms are identical, and that the phenomena related by Pasteur as resulting from the subcutaneous injection of saliva from an infant dead of hydrophobia and by myself from the saliva of a healthy adult represent the same disease? By no means. The man of science soon finds that things which look alike are not necessarily of the same kind. Thus, of two transparent colorless fluids, one may be harmless water and the other a corrosive acid; two embryos apparently alike may develop, the one into a man and the other into a monkey; two seeds of the same size and general appearance may produce, the one a cabbage, the other a turnip, &c. The argument, then, that because a certain bacillus, or spirillum, or micrococcus, is morphologically identical with another which is proved to be harmless as to its effects upon an animal organism, consequently *it* must be harmless, has no support from analogy, any more than it has from experiment. And it is high time that naturalists and physicians should open their eyes to the fallacy of such an argument, as it not only has a tendency to close the minds of those who receive it to the reception of demonstrated truths, but also acts to some extent as a bar to the progress of science in this direction.

The argument is: Bacteria are found everywhere. We eat them, we drink them, we draw their germs into our lungs at each inspiration and without apparent injury. They are evidently harmless. Your spirillum of relapsing fever does not differ (the morphological resemblance is admitted) from a harmless spirillum frequently found in the human mouth; your *Bacillus anthracis* does not differ from *Bacillus subtilis*, &c. The answer is plain. The fact that there are harmless bacteria does not disprove the possibility of pathogenic bacteria; the fact that two things look alike does not prove that they are alike; experiment proves conclusively that the phenomena of anthrax are due to the presence and multiplication in the body of affected animal of the *Bacillus anthracis*, and that in the fatal form of septicæmia described in this report the efficient cause of the morbid phenomena and of death is the minute micrococcus described. Doubtless, harmless micrococci abound. Pasteur finds no difference, morphologically, between the organism which produces the "new disease" described by him and that which produces the *cholera des poules*. He says: "By the form which it has in the blood the organism resembles the microbe of chicken cholera, but it differs completely in its functions. We may inoculate fowls with it without their experiencing the slightest ill effect. (The same is true of the organism producing the form of septicæmia described in this paper.) In the form of chaplets it resembles greatly many other organisms which I have often observed, &c.

It will have been noticed from the account already given that the fatal disease in rabbits observed by me, and resulting from the subcutaneous injection of my own saliva, resembles in many particulars the disease described by Pasteur as new, resulting from the subcutaneous injection of the saliva of a child dead with hydrophobia. Another point of resemblance is the fact that the saliva of one of my rabbits recently dead has the same virulence as the blood and serum from connective tissue. A serous liquid, which in some instances escapes from the bowels shortly before or after death, also contains the micrococcus in abundance and possesses like virulence. All of these points of resemblance form a strong probability in favor of the identity of the two diseases, but I am not prepared to pronounce a positive opinion upon this point, especially since Pasteur, who had previously given much attention to the study of septicæmia, pronounces the disease observed by him to be new. While I see no reason at present for supposing that the disease observed by me differs essentially from the experimental septicæmia produced by Davaine, Koch, and other investigators who, however, obtained their first supply of septic organisms from a different source.

In the light of what we already know, it seems very probable that purperal fever, hospital gangrene, and the various forms of septicæmia known to physicians and surgeons result from the development of pathogenic varieties of harmless and widely-distributed species of micrococci, as the result of especially favorable surroundings, such as are found in the lochial discharges of a puerperal woman or in the secretions from the surface of wounds in a crowded and illy-ventilated hospital ward.

Just as differences in resisting power to experimental septicæmia are exhibited by different species of animals, so doubtless individual differences exist in man, especially as the result of lowered vitality; and this want of resisting power, from whatever cause resulting, must be counted as one of the conditions favorable to the development and propagation of a pathogenic bacterium. Thus we find that in experimental septicæmia the micrococcus does not invade the blood until the vital powers are at a low ebb and death is near at hand.*

In the dog the vital resistence is competent to withstand the assaults of a micrococcus—injected subcutaneously—having the potency of those found in my saliva, and the result of such an injection is simply a circumscribed abcess. But the increased power (which is perhaps simply a more vigorous and rapid development) gained by cultivation in the body of the rabbit and a diffuse cellulitis results of fatal character.

The fact observed by myself that during the summer months the mud in the gutters of New Orleans possesses an extraordinary degree of virulence† shows that pathogenic varieties of bacteria are not alone bred in the bodies of living animals. The more I study this subject the more probable it seems to me that in this direction lies the explanation of many problems which have puzzled epidemiologists and that the sanitarians are right in fighting against filth as a prime factor in the production of epidemics—a factor of which the *rôle* is easily understood, if this view is correct. The presence of septic organisms possessing different degrees of virulence depending

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*By virtue of some property or mechanism at present unknown, blood, which, external to the body, is a favorable medium for the development of many species of bacteria, resists their entrance or gets rid of them when they effect an entrance, *e. g.*, by injection, so long as it is circulating in the vessels of a healthy individual.

†There is no reason to suppose that this is peculiar to New Orleans, but I have not yet had an opportunity to extend my experiments to other places.

upon the abundance and kind of pabulum furnished them and upon meteorological conditions more or less favorable constitutes, in my opinion, the *epidemic constitution of the atmosphere,* which wise men were wont to speak of not many years ago as a cloak for ignorance. It must be remembered that the gutter mud of to-day, with its deadly septic organisms is the dust of to-morrow, which in respiration is deposited upon the mucus membrane of the respiratory passages of those who breathe the air loaded with it.

Whether the peculiar poison of each specific disease is of the same nature or not—a question which can only be settled by extended experimental investigations in the future—it is altogether probable that this factor often gives a malignant character to epidemics of diseases which uncomplicated are of a comparatively trivial nature.

# APPENDIX 3.

## *CARBONIC OXIDE AS A SOURCE OF DANGER TO HEALTH IN APARTMENTS HEATED BY CAST-IRON FURNACES OR STOVES.*

By IRA REMSEN, Professor of Chemistry in the John S. Hopkins University.

In 1865 a peculiar epidemic occurred in Savoy. It was a new thing, and consequently new theories were put forward to explain it. Among these, the one which attracted most attention was that of M. Carret, who, in a communication* read before the French Academy, attempted to show that the disease was due to the use of cast-iron stoves, from which in some way carbonic oxide was given off, thus contaminating the air.

General Morin then became interested in the subject and requested† Messrs. H. Sainte-Claire Deville and Troost to make a chemical examination of the air in immediate contact with a specially constructed cast-iron stove heated to redness, as he thought that Carret's statement might possibly be explained by supposing that carbonic oxide passes through the red-hot iron, as earlier experiments of Deville and Troost had shown that this is possible. The work undertaken by the last-named chemists led them to the belief that carbonic oxide may and does pass through cast iron heated to redness. As their experiments were the first undertaken to determine whether cast-iron stoves are objectionable or not, and as the names of the chemists have carried great weight in the discussion of the question, it is desirable to know here exactly what they did:‡

They first analyzed the air of a room heated by a cast-iron stove, and found considerable quantities of carbonic oxide and of hydrogen. They then took the apparatus furnished by General Morin, consisting of a specially constructed cylindrical cast-iron stove, surrounded by an envelop of cast iron fitting into grooves in plates above and below the stove. The air was drawn out of the space between the stove and the envelope, and then passed over pumice-stone moistened with sulphuric acid and over caustic potassa. Thus freed from water and carbonic acid, it was passed into a combustion tube containing heated cupric oxide, the water and carbonic acid thus obtained weighed, and the weights of hydrogen and carbonic oxide deduced from those of the water and carbonic acid. The amounts found vary between 0.250 and 1.072 parts hydrogen, and between 0.141 and 1.32 parts carbonic oxide in 1,000 parts of air. These experiments have been justly criticised by others, and I only record the judgment of every thinking chemist when I say that the experiments do not furnish satisfactory proof of the presence of carbonic oxide in the air. In the first place there is always present in the air a certain amount of organic matter of complex nature which by combustion will yield carbonic acid and water; and hydrocarbons, which are, as is well known, formed in large quantity by the heating of coal, might also be present in the space immediately surrounding the stove. These would also yield carbonic acid and water by combustion.

A little later the French Academy, impressed with the importance of the subject, appointed a committee, consisting of MM. Payen, Morin, Fremy, H. Sainte-Claire Deville, Boussy, and Claude Bernard, to make a thorough investigation. The committee began working March, 1868, and continued until February, 1869, when General Morin, at the request and in the name of the other members, handed in an exhaustive report to the academy.§

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* Comptes rendus 66, p. 792.

† Comptes rendus 66, p. 82.

‡ Comptes rendus, 66, p. 83.

§ Comptes rendus 68, p. 1006.

The work reported upon comprised, mainly:

1. Experiments on rabbits.

By a method suggested by Claude Bernard, but not described in the report, it was determined that the blood of rabbits kept for three days in rooms heated with cast-iron stoves contained carbonic oxide.

2. Direct analyses of air of the examined rooms by the method of Deville and Troost.

3. Experiments with the above-mentioned stove used by Deville and Troost.

4. Collection of carbonic oxide itself by passing the air through a vessel containing a solution of cuprous chloride in hydrochloric acid. The gas thus collected was then set free and burned, when, from the characteristic color of the flame, the conclusion was drawn that the gas was in fact carbonic oxide.

As a result of the investigation, the conclusion was reached: That cast-iron stoves, as soon as their temperature reaches dark-red heat, cause the escape of not inconsiderable quantities of carbonic oxide, a very poisonous gas.

It is not surprising that this opinion of a committee composed of such eminent scientific authories produced a strong impression. The conclusion quoted has been pretty generally accepted as final, and cast-iron stoves have natually come into disrepute. Hot-air furnaces made of cast iron have also suffered, and "furnace-air" has often been used to signify air contaminated with carbonic oxide. The matter is evidently one of great importance from the standpoint of hygiene, and it is desirable here to inquire how far the report of the French commission can stand the test of unprejudiced criticism.

In the first place, the experiments with the rabbits, upon which so much stress is laid as proving the presence of carbonic oxide, are not fully described in the report, and, so far as I know, they have not been described since. It is impossable for this reason to determine to what extent these particular experiments may be relied upon as furnishing the evidence which they are supposed to furnish. There is only one good method known for the detection of carbonic oxide involving the use of animals, and this was introduced some years after the report under consideration was published. If the committee really used a reliable method it is strange that in the active discussion which has been carried on within the last three or four years with reference to the value of their report the details of the method have not been published. Under the circumstances it seems to be justifiable to disregard the indefinitely described experiments with rabbits.

As regards the direct analyses, the case is more difficult. The method used was the same as that of Deville and Troost, already referred to. The calculation of the results was, however, made in a different way. Instead of assuming that all the hydrogen of the water found was originally present as free hydrogen and all the carbon as carbonic oxide, the fairer assumption was made that some of the hydrogen, at least, was present as marsh gas. This would at once reduce the quantity of carbonic oxide found. The experiments show that carbonic oxide was present to the extent of 0.04 per cent., or 4 parts in 10,000, and that in some cases the amount was even greater.

It is plain from those experiments that, after the carbonic acid was removed from the air experimented on, there were left other substances containing carbon and hydrogen; and inasmuch as the amount of hydrogen present is not sufficient to account for all the carbon, assuming the two elements to be united in the form of marsh gas, the conclusion is drawn that carbonic oxide must be present. But this conclusion is by no means certainly correct, and there are mainly three good reasons for doubting its correctness until further evidence is brought forward in its support. These are:

1. The fact that hydrocarbons other than marsh gas and containing a larger proportion of carbon not only may be present, but are just as likely to be present as marsh gas.

2. The fact that there are always present in the air organic substances of unknown composition which by combustion would increase the quantity of carbonic acid found. Erisman[*] found such substances in an unoccupied and unheated room by using the method of Deville and Troost, and Dupré and Hake[†] have very recently described some experiments undertaken for the purpose of determining the amount of organic matter in the air. The last-named chemists took extraordinary precautions to remove the carbonic acid and water from the air before it was heated with cupric oxide, and they distinctly state that these precautions are necessary. While not claiming any great degree of accuracy for the figures given by Dupré and Hake, they certainly do show that the organic matter in the air should be considered in such experiments as those under special scrutiny at present.

3. The fact pointed out by Dupré and Hake, and just referred to, that it is very difficlt to remove all the carbonic acid from the air before it reaches the combustion tube. In experiments long continued and involving large volumes of air the error occasioned in this way might be comparatively large. Again, taking everything into

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[*] Zeitschrift für Biologie, XII. 328.

[†] Jour. Chem. Society, 1881, 93.

consideration that bears upon these direct analyses, it will be seen that the evidence which they afford of the presence of carbonic oxide is far from conclusive.

Much weight cannot be attached to the experiment in which the carbonic oxide was collected and afterward burned. The only evidence that the gas thus collected was really the oxide was obtained by burning a few cubic centimeters and taking the color of the flame as the test. It cannot be denied that other things may have been present, and that the test was a very unsatisfactory one. These few critical remarks are intended to show that the subject under consideration cannot be regarded as exhausted, and that after the report of the French commission new evidence either for or against the correctness of the conclusion drawn was loudly called for.

A few years ago H. Vogel called attention to a very pretty and delicate method which he recommended as well adapted to the detection of small quantities of carbonic oxide. The method depends upon the action of the gas on blood, and consists in shaking with a little blood the air to be examined and then examining the blood with a spectroscope, the presence of carbonic oxide being revealed by a peculiar absorption spectrum which will be described below. Vogel claims that by this method 0.4 per cent. of the gas can be detected in the air. In a later article the same author describes some special experiments, undertaken at the request of the authorities of the city of Berlin, for the purpose of determining whether carbonic oxide was present in the air of certain school-houses in that city. Although Vogel succeeded in increasing the delicacy of his method, so that he could certainly detect 2.5 parts of the gas in 1,000 parts of air, he was unable to find any evidence of its presence in the buildings examined by him.

J. Gottschalk was also requested by the authorities of the city of Leipzig to examine the air of certain school-houses, and in 1877 his report was published in full, under the title: "Ueber die Nachweisbarkeit des Kohlenoxyds in sehr kleinen Mengen und einige Bemerkungen zu per sogenannten Luftheizungsfrage." (Leipzig, Barth.)

The method used by Gottschalk consisted in passing the air to be examined through a neutral solution of palladium chloride. When carbonic oxide passes through such a solution it exerts a reducing action; small, black flakes of the metal appear, and the presence or absence of the gas may be judged of by the presence or absence of the black flakes. It is undoubtedly true that carbonic oxide acts in the way described, and that very small quantities of it may be detected by means of the reaction mentioned; but it is also true that certain hydrocarbons which are likely to be in the air in the neighborhood of stoves and furnaces act in the same way. Hence, if the solution of palladium chloride were changed by the air, we should have evidence of the presence of either carbonic oxide or hydrocarbons, or, possibly, some of the easily oxidizable organic matters always present in the air. If, on the other hand, no change were produced, we might fairly conclude that carbonic oxide is not present, at least not in quantity greater than that which the method is known to be able to detect. According to Gottschalk, the method is competent to detect 0.22 parts in 1,000 of air, a fact which was established by a series of experiments undertaken specially for the purpose. In the air of the school-houses Gottschalk found no evidence of carbonic oxide, from which fact the conclusion may be drawn that the gas was not present to the extent of 0.22 parts in 1,000.

The negative results obtained by Vogel and Gottschalk have led to several examinations of a similar kind. In 1878 there appeared an article,[*] by S. Wolffhügel, in which some of the earlier experiments are subject to criticism, and some new experiments are described. The article opens with a criticism of the results of R. Kaiser,[†] who found carbonic oxide in the air of the *Gewerbemuseum* at Nürnberg. The gas was detected by oxidizing with chromic acid solution, and also by absorption in a solution of cuprous chloride in hydrochloric acid. As Kaiser does not describe his experiments with sufficient accuracy to enable the reader to judge of their value, and there are so many precautions necessary in order to insure success, his results are entirely disregarded.

Aug. Vollert[‡] has also stated that he had detected carbonic oxide in the air of the Johanneum at Hamburg; but the method used by him is the old one of Deville and Troost, and he entirely neglects the hydrocarbons, so that no weight can be attached to his results.

Wolffhügel's own experiments consisted in making a box on the side of a cast-iron stove so that one square decimeter of cast iron, that could easily be heated to redness, was covered by the box. The box ended in a tube by which connection was made with an aspirator. The air was then examined by means of Vogel's blood-test. By means of this test he was able to detect carbonic oxide in tobacco smoke; but in all his experiments with the cast-iron stove the results were negative.

Several important details are lacking from Wolffhügel's description of his experiments. It is not stated, for example, what relation the piece of cast iron which was heated to redness bore to the heated coal within the stove, whether it was above the coal or the coal came in contact with it. The thickness of the plate of iron is also not mentioned.

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[*] Zeitschrift sür Biologie, 14, 506.

[†] Mittheilungen des bayer. Gewerbemuseums 1877, Bd. I, 2.

[‡] Ueber Luftwechsel und Beschaffenheit der Luft in den ventilirten Räumen des Johanneums. Hamburg, 1878, 22.

Some experiments with cast-iron tubes were next tried. The walls of these tubes were $0.35^{cm}$ to $0.65^{cm}$ in thickness, and their internal diameter was from $2.5^{cm}$ to $5^{cm}$. They were placed in blast-furnaces and heated to redness. The air drawn through them contained considerable quantities of carbonic oxide, which was easily detected.

Within a short time past several suggestions have been made looking towards the increased delicacy of the method for detecting carbonic oxide. Among these may be mentioned those of Th. Weyl and B. Anrep[*], of C. H. Wolfft[†] and S. v. Fodor.[‡] None of the suggestions appear to have been followed up very closely, and the papers in which they are described contain no satisfactory evidence in favor of the methods employed. There is one method, however, which deserves special attention as it has been tested very carefully by the inventor, and seems to be admirably adapted to the detection of very small quantities of carbonic oxide. This is the method described by W. Hempel.[§] It consists of a modification of Vogel's blood-test. By passing air to be examined through dilute blood, Vogel could detect 2.5 parts of the gas in 1,000 of air. Hempel concentrates the effect of the gas by allowing small animals (mice) to breathe the air for a considerable period. He then kills the animals and examines the diluted blood with the spectroscope. By this means it was found that a much smaller amount of the gas can be detected than by the original Vogel method. The limit stated by Hempel is 0.5 part in 1,000, or about one-fifth the limit given by Vogel. Hempel contented himself with proving the value of the method. He mentions no experiments involving the application of his method, nor has it, as far as I can learn, ever been practically used in investigating the question regarding the presence of carbonic oxide in the air of rooms.

In view of the uncertainty connected with the subject and its evident importance, it seemed to me to be desirable to undertake a new investigation, using that method which, after careful study and comparison, should prove best fitted for the purpose; and, at the request of the National Board of Health, I have for some time past been engaged upon the work, in the experimental part of which I have had the valuable assistance of Mr. D. T. Day.

The question which I proposed to answer as far as it lay in my power to do so was this: Is carbonic oxide a constituent of the air of rooms heated by cast-iron stoves and hot-air furnaces, particularly if these are of bad construction and in bad condition? There are plainly two sources of danger to keep in mind: 1st. The passage of carbonic oxide through cast iron heated to a high temperature; and, 2d. The escape of the gas from fissures in the wall of the stove or furnace.

A careful study of the methods which have been used in all the earlier experiments led me to the belief that better results could probably be obtained by the use of Hempel's method than by any other, though, of course, much depends upon the accuracy of Hempel's statements. If the method is as delicate as is claimed, then it is better adapted to the purpose of such an investigation as this than any other which has ever been used. Accordingly, I first undertook an examination of the method itself, for the purpose of convincing myself of its value. I may say at once that my own experiments fully confirm the statement of Hempel concerning the delicacy of the method, and after an examination of other methods and a comparison of them with this one, I am fully convinced that it is the best one now at our command for the purpose for which it is intended. In order that the experiments described in this report may be intelligible to those who have not familiarized themselves with the method of Vogel already referred to, and of which that of Hempel is a modification, I give here a brief description of the method as used by myself.

## THE VOGEL-HEMPEL METHOD OF TESTING FOR THE PRESENCE OF CARBONIC OXIDE.

The original method, as given by Vogel[‖], is thus described: "If it is desired to test the air of any room with reference to the presence of carbonic oxide, it is best to empty in the room a flask of about $100^{cm^3}$ capacity and filled with water. In the empty flask there are then poured $2\text{–}3^{cm^3}$ of blood, so strongly diluted with water that it is only faintly colored red, but at the same time distinctly gives the two known absorption bands when examined in a small test-tube with the spectroscope. If this solution is shaken with the air only one minute, the action of carbonic oxide, if it is present, can be seen even in the change of color of the blood. It appears more of a rose color; the absorption bands are a little paler, less distinct, and moved a little farther to the left than those of pure blood. This change alone is sufficient to enable a skilled spectroscopist to detect the presence of carbonic oxide.

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[*] Berichte der deutschen chemischen Gesellschaft, XIII, 1294.

[†] Correspondenzblatt des Vereines analytischer Chemiker. 1880, 46.

[‡] Vierteljahresschrift für öffentliche Gesundheitspflege, 1880, 377.

[§] Zeitschrift für analytische Chemie, XVIII, 399.

[‖] Berichte der deutschen chemischen Gesellschaft, X, 793, and XI, 235.

"Those who are less skilled may convince themselves, however, by the addition of 3–4 drops of strong ammonium sulphide, which, as is well known, causes the disappearance of the two bands of pure blood, and the appearance of a broad, indistinct shadow in their place, while the bands of the blood which contains carbonic oxide are not changed by ammonium sulphide."

The smallest quantity of the gas which Vogel could detect was 2.5 parts in 1,000. Hempel's modification of the test consists, as already mentioned, in allowing mice to breathe the air under examination, killing the mice and then proceeding with the blood as Vogel recommends. The mouse used is placed in an apparatus made of two glass funnels joined together at their mouths by means of a wide rubber band. The air is drawn through this apparatus by means of an aspirator, and at the end of the experiment the mouse is killed by the most convenient method. I have found it best to drop the animal into a tall and narrow cylinder, and to fill this completely with water, bringing down upon its mouth a glass plate. In a very short time death follows. The mouse is then brought into a small, clean beaker with a little water, and cut in two in the neighborhood of the heart by means of a pair of small, sharp scissors. On squeezing the pieces with a pestle enough dilute blood is easily extracted for the observations. If the mice have been used to examine the air of buildings situated away from the laboratory, the dilute blood, obtained as above described, is best brought into strong glass tubes, so as to completely fill them, and the tubes then tightly corked and taken to the laboratory for examination.

In order to thoroughly accustom ourselves to the use of the method, my assistant and myself made a series of observations, the results of some of which are here recorded.

1. Into a gasometer, the capacity of which is 16,750$^{cm^3}$, and which was filled with air, there were introduced 83.75$^{cm^3}$ CO, so that the air contained 0.5 per cent. of the gas. The mixture was allowed to stand about 20 hours to secure thorough mixture of the gases; 10 liters of the mixture were now passed through the Hempel funnel, in which a mouse was placed. In five minutes the mouse appeared to show symptoms of poisoning, and in half an hour it could hardly move. The spectrum of CO was very distinct. The time occupied in the passage of the 10 liters of air was two hours.

2. In the same gasometer as that used in the first experiment, 33.52$^{cm^3}$ of CO were introduced with air, the mixture thus containing 0.2 per cent. CO. In other respects the two experiments were identical. The mouse was plainly affected. The blood spectrum gave unmistakable evidence of the presence of CO.

3. 10$^{cm^3}$ CO in gasometer mixture contained 0.06 per cent. CO. Time, 2¼ hours. Volume of gas, 15 liters. CO sprectrum easily recognized, particularly by comparing the blood with that of a mouse unaffected by the gas.

4. Air contained 0.05 per cent. CO. Time, 3 hours. Volume of gas, 14.5 liters. CO spectrum recognized.

5. Air contained 0.04 per cent. CO. Time, 2¼ hours. Volume of gas, 14.5 liters. CO spectrum recognized, but weak.

While the experiments thus briefly described will serve to give an idea of the character of our preliminary work, it should be mentioned that each one of the experiments was repeated a number of times with the object of thoroughly accustoming our eyes to the characteristic features of the carbonic oxide spectrum. These repetitions were especially desirable in the last experiments involving the smallest quantities of the gas. At first we were unable to detect 0.05 per cent. with any degree of certainty, but after considerable practice with small quantities we had no difficulty in detecting 0.04 per cent. This is less than the lowest limit mentioned by Hempel, viz, 0.05 per cent., but there can be no doubt in regard to the accuracy of this statement. The experiments with 0.04 per cent. were frequently repeated, and we subjected ourselves to such conditions as to make self-deception impossible. Several specimens were prepared by my assistant, some of them being affected with carbonic oxide, and the rest not; without any knowledge in regard to the nature of the different specimens, they were examined by me, and, after the necessary practice, those which were contaminated with carbonic oxide were detected unerringly. The same process was then reversed. I prepared the specimens, and my assistant detected those which contained the carbonic oxide as readily as I had done. Having thus trained ourselves for the work with this method, and being thoroughly convinced that we can detect carbonic oxide in air when it is present to the extent of 0.04 per cent., or *four parts in ten thousand*, it remained to examine the other methods for which great delicacy has been claimed.

By agitating 10$^{cm^3}$ of blood from five to seven times, each time with about six liters of the air to be examined, heating the blood to 90–95°, and passing a current of air through it, and then through an aqueous solution of palladium chloride containing one part of the chloride to 50 of water, S. von Fodor[*] claims to be able to detect the presence of 0.5 part of carbonic oxide in 10,000 of air. By this method he claims to have detected carbonic oxide in the blood of rabbits which had been kept for some time in an atmosphere containing only 0.4 part of the gas in 10,000 of air. He also recommends the use of test papers prepared by moistening fine filter paper with a 0.2 per cent. solution of palladium chloride; and states that if the air contains $\frac{1}{2000}$ of carbonic oxide the paper becomes covered with a black film in a few minutes; if $\frac{1}{10000}$ the change is effected in 2 to 4 hours; if $\frac{1}{20000}$, in 12 to 24 hours.

The difficulty with this test has already been pointed out. Other substances besides carbonic oxide exert a reducing action on palladium chloride, and the separation of minute quantities of palladium can scarcely be regarded as furnishing very strong evidence of the presence of the gas. I have made a number of trials with this method of von Fodor, but I have not been able to get results as good as those described by him, nor as good as those which I could easily get by using Hempel's method. It may be that in my experiments some essential conditions were not fulfilled, but, at all events, the fact remains that, striving earnestly to give the method a fair trial, I could not finally accept it, and I certainly cannot indorse the statements of von Fodor concerning it.

The same writer claims, further, that the color reactions of blood containing carbonic oxide are better adapted to the detection of the gas than the spectroscope. He recommends that the blood be shaken with ammonium sulphide in a test tube, and then examined by transmitted light. If it contains carbonic oxide it appears red; if not, it is turned violet. This difference in color is said to be recognizable when the blood has stood in a flask of ten liters' capacity in contact with air containing 0.05 per cent. carbonic oxide. I examined this method carefully, but soon became convinced that it possessed no advantages over the Hempel method, and the results seemed always to be less reliable. While I never failed to detect 0.04 per cent. of the gas by the latter method, 0.05 per cent. was the least that I could detect by means of the color reactions; and I found that the opinion of neither my assistant nor myself could be relied on when it was based solely on an examination by this latter method.

As a result of the work thus far described, then, it will be seen that there is a method, the indications of which are unmistakable, and which renders it possible to detect the presence of 0.04 per cent. of carbonic oxide air.

Armed with this method, the next step in the investigation was, of course, to apply the method to the examination of the air of such buildings as seemed to be most suspicious. The indiscriminate examination of buildings without previous careful inquiry in regard to the condition and character of the heating apparatus used in them was not desirable. It seemed best to inquire first of those most likely to be informed in regard to the condition of furnaces in various public and private buildings in this city. Accordingly, a number of the city officials, including the health commissioner, fire commissioners, and others, and several of the leading manufacturers of furnaces and stoves, were visited, and asked for the desired information. My thanks are due to all these, who so readily responded to the questions asked. Much valuable information was gathered in this way. It is unnecessary to go into details in regard to the places which we selected for examination. Suffice it to say that from first to last the air in a comparatively large number of rooms was examined. Whenever a particularly bad furnace was heard of, mice were stationed in the immediate vicinity of the hot-air flues connecting with it. If any special complaint was heard regarding bad air supposed to be caused by a furnace or stove, mice were put on the scent. It is believed that in some of the places examined there were as bad furnaces as could well be found anywhere. Not infrequently the disagreeable "close" character of the air was very striking. In short, it is believed that the examination was as thorough as it is possible to make it. The result of the examination is simply this, that *carbonic oxide was not detected in a single case, and the conclusion is justified that in rooms heated by cast-iron stoves and furnaces there is not present in the immediate vicinity of the hot-air flues as much as* 0.04 *per cent. of carbonic oxide.*

This result is in accordance with those reached by Vogel, by Gottschalk, and by Wolffhügel, referred to in the earlier part of the report, and cannot be disregarded in any future discussion of the question under consideration.

Another question remains to be answered, and that is whether carbonic oxide in smaller quantities than those which can be detected by Hempel's method may not be present. There is not, however, any reliable method for detecting smaller quantities, so that the question is as yet unanswerable. It is also very difficult to decide whether such small quantities of the gas are injurious to health or not. I have not undertaken any experiments on this point. Those who have discussed it differ in their opinions.

H. Vogel thinks that any quantity of carbonic oxide which cannot be detected by his original method cannot be dangerous. He says: "When the air of a room, containing a very small quantity of carbonic oxide, has not the power to react on the very dilute blood used, this air also has no power to poison the much more concentrated blood of the human lungs. The large quantity of oxygen acts as a natural antidote, and I consider the presence of smaller quantities of carbonic oxide in the air than 2.5 parts per thousand as decidedly not injurious. Indeed it is possible that the human organism may be able to endure even a larger quantity, for it is a fact that in tobacco smoke, which is inhaled by millions, carbonic oxide can be easily detected by means of the blood-test, and, judging by the strength of the reaction, the gas is present in the smoke in larger quantity than 2.5 parts per thousand. It is probable that the harmfulness of small quantities of carbonic oxide has been overestimated."

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[*] Vierteljahresschrift für öffentliche Gesundheitspflage, und Zengler's Polytechnisches, 1880, 377, CCXXXIX, 456.

Wolffhügel accepts Vogel's view, and suggests this guide for sanitarians, that as long as air does not contain enough carbonic oxide to be detected by Vogel's test (that is, 2.5 parts per 1,000) it may be regarded as uninjurious.

On the other hand, von Fodor takes quite a different view of the matter. According to his experiments, when air contains 4 parts of the gas in 1,000, rabbits become unconscious in it in four hours; if 3 parts are present the effect is reached in 24 hours, and even with 1.3 parts decided symptoms are produced when the air acts for several days on the organism. But man is more sensitive to the action of carbonic oxide than animals, as Friedberg has shown in his treatise, "Vergiftung durch Kohlendunst" (Berlin, 1866), and as follows from the fact that animals easily recover from unconsciousness, whereas human beings usually die if they once lose consciousness. * * * Further experiments with rabbits showed that even 0.5 parts per 1,000 of carbonic oxide causes difficulty in breathing; the animals staggered and took no food, and were sleepy when the quantity of the gas was reduced to 0.25 parts, so that in this dilution it must be regarded as injurious to health. The views of von Fodor may be summed up briefly, thus: As 1.5 parts of carbonic oxide per 1,000 of air are dangerous to health, 0.5 parts, when inhaled for considerable time, are injurious, and 0.04 parts are not without influence, it is desirable that the heating apparatus and gas-pipes in public institutions and private dwellings should be examined with reference to the question whether they permit carbonic oxide to enter into the air used for breathing.

To decide between these widely differing opinions is not part of the work which I originally had in mind. It does not, indeed, belong to a chemist to deal with such matters. The only point I would make in this connection is that it is better to err on the safe side, if err we must. If carbonic oxide can be detected by any method in the smallest quantities in air to be used by human beings, measures should be taken to prevent its further presence.

The cases thus far experimented upon are such as were actually met with in occupied buildings. While the uniformly negative results made it appear probable that experiments with any specially constructed stoves would also yield negative results, I thought it desirable before closing the investigation to test the matter somewhat further. Through the kindness of Messrs. Hutchinson Brothers, manufacturers of furnaces in this city, I was furnished with a stove of peculiar construction for the purpose of further experiments.

Since the investigation of the French commission, in which a cast-iron stove was used, no experiments except those of Wolffhügel have been made on stoves specially constructed for the purpose of determining whether carbonic oxide passes through cast iron heated to redness or not. As the method of detection used by the French commission is not infallible, and as that used by Wolffhügel is not as delicate as the one used in this investigation, it was thought that possibly the use of the more delicate method might show that the gas really does pass through, as stated by the French commission, though denied by Wolffhügel. Two kinds of experiments were performed: 1st. Those in which the air examined was drawn from the top of the stove consisting of cast iron heated to redness; and 2d. Those in which the air was taken from a space on the side of the stove in direct contact with the hot coal.

The stove used is a simple cylinder of wrought iron about two feet high and one and a half feet in diameter. It is so arranged that it can be filled with coal, and the supply of air regulated with ease. The top is a piece of cast iron carefully fitted to the cylinder by an air-tight joint. At the side of the cylinder is a space about six inches square furnished with carefully made grooves, into which plates of cast iron of different thickness may be placed, and fitted in air-tight if necessary, with luting.

*Experiment* 1. The stove was heated to as high a temperature as possible, so that the top of cast iron was nearly all white hot. The temperature was kept about the same throughout the experiment, the dampers being closed the greater part of the time. A metallic funnel was brought down close to the hot plate; this was connected by rubber tubing with a glass U-tube placed in water for the purpose of cooling the air; then connection was made with the double funnel containing the mouse, and by means of an aspirator air was slowly drawn through the whole system. Twenty liters were drawn through in one and a quarter hours. The mouse was killed and the blood immediately examined, but the spectroscope failed to reveal the presence of any carbonic oxide.

*Experiment* 2. The same stove was used as in the last experiment, but a piece of cast iron $\frac{3}{8}$ inch in thickness was introduced so as to form part of the side of the stove. The coal in the stove was above the top of the cast-iron plate, and the plate was kept considerably above red heat during the experiment. The funnel was applied to this plate and the experiment was, in other respects, conducted the same as the last one. No evidence of the presence of carbonic oxide was obtained.

*Experiment* 3. Same as experiment 2, except that the cast iron-plate used was thinner, being from $\frac{1}{4}$-$\frac{1}{8}$ of an inch thick. The space from which the air was drawn was white hot. No carbonic oxide found. Special precautions were taken to prevent the mouse from breathing fresh air in the brief interval from the time the passage of air was stopped until the mouse was killed, which was of course as soon as possible. On stopping the aspirator, both ends of the Hempel funnel were closed; one end was then connected with the hydrant and the air displaced by water.

*Experiment* 4. Same as Experiments 2 and 3. The plate in this case was $\frac{1}{16}$ of an inch in thickness. No carbonic oxide found.

All these experiments, then, it will be seen, give negative results, and show that under apparently the most favorable conditions not as much as 0.04 per cent. of carbonic oxide passes through heated cast iron.

In view of the accumulating mass of testimony, of which this report furnishes a part, against the correctness of the conclusion first authoritatively stated by the French commission, it appears to be highly desirable that the work of the commission should be repeated, account being taken of the influence of the possible sources of error to which attention was called in the first part of the report. The work would be tedious and would require the greatest possible care, but the importance of the question involved would justify the necessary expenditure of time. If this work were repeated it might be possible to discover what the real cause of the bad effects of furnace air is.

In conclusion, I will only say that, in view of the results reached in these experiments, and those of some earlier experimenters which have been referred to, the confident references to carbonic oxide as a source of danger to health in rooms heated by hot-air furnaces and cast-iron stoves, which we so frequently hear, certainly should be modified to accord with what is actually known. The hypothesis is perhaps justifiable that carbonic oxide is present in such rooms, but not that it is present in quantities as great as 0.04 per cent.; and it remains to be shown whether such minute quantities of the gas, if present, can act injuriously on the health of those who breathe it.

# APPENDIX 4.

## *REPORT OF THE RESULTS OF AN EXAMINATION MADE IN 1880 OF SEVERAL SEWERAGE WORKS IN EUROPE.*

By RUDOLPH HERING, *Civil and Sanitary Engineer.*

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PHILADELPHIA, *June* 28, 1881.

THE NATIONAL BOARD OF HEALTH,
*Washington, D. C.:*

GENTLEMEN: In compliance with your request of May 10, 1880, and also of May 25, 1881, I respectfully submit the following report, containing the results of my examination of several European sewerage works.

Very respectfully,

RUDOLPH HERING.

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## I. INTRODUCTION.

The existing diversity of opinion regarding the best method of removing offal and waste-water from houses and towns can, I believe, be explained, at least partially, by certain difficulties which meet us in rightly judging the numerous methods and designs. It will, therefore, be proper at the outset to ascertain their nature and examine their bearings.

In comparing the views of the gentlemen directly and indirectly interested in the sewage question, it can be observed that the habitual engagement of the mind in certain directions tends greatly to influence opinions, and to cause what may be termed a professional bias.

It can be observed in Europe, as a rule, that chemists, physicians, and agriculturists are prominent among the opponents of the water-carriage system. They point to the injurious effects of soil contamination by sewers, of the gases and germs emanating from them, of the pollution of river and subsoil-water, and to various dangers which are expected to arise from sewage farming. On the other hand, they dwell on the manurial value of undiluted excreta, and the national importance of preventing its waste. All these considerations come within the range of their professional studies.

Again, we can notice that engineers, who find themselves confronted by problems such as the removal of storm-water from the surface of the streets of subsoil-water and house refuse, also the construction and cleaning of streets, the supply of water to dwellings, its subsequent removal, and, finally, the restriction to the utmost economy of expenditure, are quite generally in favor of water-carriage.

But, also among the latter alone, we discover a division of opinion. Municipal engineers of large cities with closely built-up districts and well paved streets, who have been obliged and accustomed to provide for the rapid removal of rain-water and the protection of cellars, &c., have generally indorsed the so-called "combined" system of drainage for all towns; *i. e.*, leading rain-water and sewage into the same sewers.

Among the engineers who have drained small towns, where usually quite other conditions present themselves, the "separate" system is often favored, where sewage and rain-water are removed in different channels; but we find it likewise recommended for all towns. Finally, even some of the details of each system form points of dispute.

An inspection of the different methods and works seemed to reveal the fact that advocates frequently lay too much stress on the advantages, and opponents exaggerate the defects of systems.*

In order to obtain a truer judgment, it is necessary to be aware of this unconscious bias and eliminate any warped opinions or relatively insignificant facts and bearings, and realize the essential features in each case.

The engineer, for instance, should be as conscious of the sanitary demands and

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*Dr. Pettenkofer, the celebrated hygienist, who, at first, quite naturally, was an opponent of water carriage, altered his opinion after a thorough scrutiny of the other demands upon a city and the capabilities of engineering science.

*rational* economy of his works, as his opponents should be careful to look into the nature and necessity of other city requirements, into the technical feasibility of one structure satisfactorily serving several objects, and into the question of *municipal* economy.

Judgment is also sometimes misguided by ignorance of the particular circumstances under which certain sewerage works have grown to their present state.

The financial necessity of making the best use of existing structures has often caused new designs to be quite unlike what they would have been under different circumstances. Improvements are sometimes severely criticised for this reason, although they were the best that could be done under all the governing conditions.

The physical features of a town will greatly influence the character of design, and, if not rightly understood, also give cause for erroneous opinions. The main drainage of London has frequently been attacked as being a wrong solution of the metropolitan drainage problem, yet the enormous population, the topography, the proximity to the ocean, the inexpediency and expense of a thorough purification of the sewage, quite justified the authorities in adopting the present system.

We hear the sewerage of Memphis objected to on account of the exclusion of rain-water. Yet, when considering that there was an urgent necessity of speedily and cheaply sewering the unfortunate town, this feature is fully justified, especially when considering the surface characteristics of its site. On the other hand, it would be a like error to recommend the exclusion of rain-water, or the separate system for all cities, as a few parties have advocated in England and this country.

The customs of the people can also materially influence the design, at least of details, which circumstance, if not considered, calls out an erroneous judgment. The liberal use of water, for instance, in the many restaurants and fountains in Munich, where it is allowed to run continuously to insure coolness for drinking purposes, facilitates arrangements for flushing which in other towns might be impracticable. The pail system has been unreservedly condemned by certain persons because it was found objectionable in connection with the use of water-closets, or because it was offensive from not receiving proper attention. Its efficiency for economical or other reasons where water-supply or sewerage is not available has been ignored.

Lastly, we can discover a difficulty in rightly judging the works of a city in the fact that innovations or changes are frequently resisted by those in charge either from a force of habit in adhering to old customs or from the inconvenience of altering existing laws. Although these obstacles are slight, they are distinctly noticeable, and, unless realized, often assist in warping the judgment of a particular case.

It will thus be seen that a careful inquiry into various points must be made before we can understand the numerous works and designs, and that we must be aware of the fact that some opinions are given from a sanitary point of view alone, others solely from financial considerations, or from conclusions gained in dissimilar localities to those in question.

My inspection has led me to believe that the present divergence of views is mainly due to one or more of the above causes.

The sewerage question must be treated from two aspects. As the works are to receive, convey, and discharge organic waste products, the decomposition of which is, either directly or indirectly, the cause of unhealthful influences, it is necessary to examine them first of all from a *sanitary* point of view. When a satisfactory standard in this direction can be reached the next inquiry is into the expense attached to their execution, in other words, into the least possible *cost* at which a sanitary condition can be attained.

These two considerations alone decide their merits. It will be found that several of the systems, if properly designed, constructed, and maintained, will have no serious sanitary defects, and that their relative advantages will depend mainly on the question of cost. As the latter varies with the local conditions, it is evident that these will almost wholly determine the selection of the system.

I will now briefly examine into the different methods and systems, holding the above points in view, in order to determine their relative value and applicability.

## II. GENERAL SYSTEMS AND THEIR APPLICATIONS.

In general, two methods have been proposed to satisfy the sanitary stipulations: the "dry removal" and "water carriage."

The former accomplishes its object either by an immediate and thorough disinfection with subsequent removal at convenient intervals, or by temporary storage with frequent removal before decomposition can be rendered injurious, and the latter by an immediate and continuous self-removal.

The common cess-pit shall not be considered, as it, generally speaking, violates the sanitary requirements.

For isolated country houses, however, its defects will be insignificant, and where the expense for a cleaner contrivance cannot be afforded it may be considered admissible, if not situated near the dwelling, and when the contents cannot pollute any drinking water. In several European cities cess-pits are prohibited; in our own cities their use is still indorsed, and, because they require the least outlay of money, are in fact the prevailing system.

### 1. *Dry removal.*

Among the methods for dry removal, there are but a few which can be recommended from a sanitary point of view.

*Disinfection.*—In order to retard, if not prevent, the escape of dangerous effluvia, certain substances are regularly added to the receptacle containing the excreta and other decomposable waste matter of the house; and the whole is removed at convenient intervals.

Two means can be employed, either absorption, by which oxidation is facilitated by the porosity of the material, or decomposition and conversion of injurious compounds into uninjurious ones.

The former is accomplished by dry earth or charcoal, &c., the latter by carbolic acid, chloride of lime, creosote, &c. To render the disinfection perfect it is necessary to add the material after every evacuation and in sufficient quantities.

Although this method is efficient, yet its trouble and expense, as is easily seen, excludes it from extensive application in large cities. Yet when none other is available, it gives, with the proper materials, appliances, and proper management, quite satisfactory results.

The well-known dry-earth closet is one of the best examples under this head, and the conditions under which it can be recommended are small country towns, villages, or isolated buildings, without water supply or sewerage; provided, particularly in the former case, a central authority arranges for the regular supply of fresh earth and the removal and sale of the resulting manure.

*Casks and pails.*—If offal is to be temporarily stored near the premises, and not disinfected, but frequently removed (*i. e.*, from one to seven days), it requires to be inclosed in casks, pails, or tubs, so that a free access of oxygen and a consequent rapid decomposition, as well as the escape of effluvia, is prevented as much as possible. This method is very common in Europe, especially on the Continent, and as it has been given the preference over all others by some authorities, a short description is not out of place.

Oak or iron pails or casks, of sizes ranging with the locality and frequency of removal, are placed under the soil-pipe, which enters the lid generally with a closely fitting joint. There are two kinds in use, one receiving all excreta, the other permitting the fluids to filter through a sieve, forming a vertical partition, and to flow off into a sewer. The latter, which is much used in Paris, and since June 23, 1880, has been made obligatory for all new buildings on sewered streets, is called a "fosse filtre." One-fifth of all houses in Paris are thus supplied. The capacity of the "fosse" is from 100 to 125 liters, and as it does not retain fluids it fills up less rapidly and needs to be exchanged less often. To prevent a consequent greater decomposition and dissemination of various gases, the casks should be, and sometimes are, very carefully sealed. The liquids, which are the more putrescible substances, are by this method allowed to get into the sewers, making it an intermediate step between dry removal and water carriage.

The municipal engineers of Paris, who mostly favor the latter, consider the fosse filtre an advisable transition from the common pail system (fosse mobile), which is still used by nearly four-fifths of the community, to water carriage, because they are obliged to act subserviently to the great popular prejudice against introduction of fæces into sewers.

These circumstances should be understood, because to start anew with this device would certainly be objectionable, for it requires in addition to a system of sewers exactly like one designed to include the conveyance of fæces, the extra expense and annoyance (not to speak of the sanitary aspects) of the removal of a substance for which scarcely any money is given by the farmer, as the more valuable ingredients have been washed out. Its discharge into the sewers, moreover, would hardly be noticeable, because a great quantity of filth is already present, which is well demonstrated by the composition of the Paris sewage itself.

When the success of the irrigation fields below Paris has become fully appreciated by the inhabitants, and after they are extended so as to dispose of all the sewage (now only one-sixth is utilized), it is the intention to simply remove the "fosses filtres" and insert in their place a few lengths of pipe, and thus ultimately get a complete water-carriage system.

A far more extensively used cask, one which is entirely independent of a system of sewers, is the ordinary "fosse mobile" of France, the "tonne" of Germany, or the "pail" of England. They are simple barrels or tubs, retaining the excreta, and are usually exchanged at intervals varying from one day to one week. Their contents are in a good condition to be sold and used as manure, which, when the transported distance is not too great, often allows a margin for profit on the expense for collection. When removed every one to three days in vans with air-tight doors, when well cleaned at the depot and provided with properly fitting lids and pipe attachments while in use, the cask system has no decided sanitary imperfections. This circumstance on one hand, the expense of sewers and dangers of sewer gas, resulting from improper construction or management of the latter, on the other, have brought out many advocates of the system, especially in Southern Germany, where it is the prevailing one, and where, in some instances, it is exceptionably well managed.

To compare favorably with water-carriage systems, however, it must be restricted to—

1. Small towns, on account of the expense of cartage;
2. Towns where the regular exchange of the pails can be enforced with almost military strictness, which is seldom found outside of a few European countries;
3. Dwellings where water-closets cannot be used;
4. Localities where sewerage would be very expensive ; and
5. Where the waste water can be led over the surface of the gronnd without causing offense.

These restrictions may often cause a close competition with the "dry-earth closet." From a sanitary point of view the latter has slightly the preference, because it disinfects the filth; yet it is more expensive on account of the additional cost, supply, and removal of the earth or other substance used as disinfectant.

It will depend, therefore, entirely on local requirements and peculiarities to determine which of the two methods is more desirable.

### 2. *Water-carriage or sewerage.*

It is now in place to consider sewerage proper, which is a system of continuous underground pipes or channels, causing an immediate and complete self-removal of all excreta and waste water from the dwelling to the place of final disposal.

To rightly understand certain present conditions, it will be well to glance briefly at the history of the subject.

The first sewers in the more modern European towns were obtained simply by arching over the natural water-ways, which had become fouled by general refuse continually cast into them. Their position along the valley lines required a size sufficient for the conveyance of storm-waters.

After the introduction of a regular domestic water supply into cities, there was an increased supply of dirty water running off in the gutters, causing filth and insalubrity both in winter and summer; and it was proposed to lead this house-water, together with the street washings, directly into the sewers. But the improper construction of the later caused a storage rather than a removal of the filth, and their condition, before a heavy, cleansing rain, was about as offensive as a common cess-pit. A sewer was synonymous with all that is repulsive, filthy, and disgusting. Under such conditions it was suggested in England that the introduction of human excreta by means of water-closets could not materially add to the nuisance which was considered unavoidable, as the additional amount of water was enough to flush away the additional amount of floating solids, while the degree of cleanliness attained in our dwellings would be much greater than through the use of any other appliance for removal.

The idea grew in favor wherever extensively tried, and it became evident that the water carriage of excrements was rapidly supplanting dry removal.

However, the foul conditions of the sewers and their sanitary evils grew worse in proportion to the density of population. This was attributed by many entirely to the introduction of water-closets, which were accordingly opposed; by others, to imperfections in the sewers themselves. It was recognized that if water-carriage was to answer the general hygienic requirements. radical changes were necessary in design and construction to prevent deposit and storage of filth. Investigations were therefore made with reference to grade, shape, &c., to facilitate a complete and rapid removal, and enough was learned to see a practical possibility of attaining good sanitary conditions. Then, as it was found that most of the old existing sewers could not be made to answer the new demands, mainly on account of their shape and grade, it became a question of economy whether they should be entirely replaced or used for a purpose less exacting. This circumstance gave origin to the "separate system," when rain-water alone flowed into the old sewers, the house drainage being led away by a new system of very much smaller pipes. A small amount of rain-water was turned into the latter from back roofs and yards, in order to give them an occasional flushing. When, however, no old sewers could be systematically utilized in this way, and the rain-water removal was an important consideration, we find that the "combined system" was adopted, leading off rain-water and sewage by the same channels, as in the larger cities of Europe and here.

Another phase of the question now appeared. The extension of sewers increased the amount of filth discharged into the rivers, causing a pollution of perhaps the only available source of drinking water for other towns. This new trouble was mostly felt in England, where the population is dense and the rivers are small, and where it consequently has attracted the greatest attention.

Unless the "pail system" could be resorted to and restrictions placed on the quality of water led into the old sewers (which was done in the towns of Rochdale, Halifax, &c.) a sufficient purification of the sewage before discharging into the rivers became the only alternative.

Great efforts were made to discover an efficient process, and they were encouraged by extravagant hopes of gaining a valuable manure. Views differed greatly and much discussion was elicited. Yet enough experience has been gained to indicate a fair solution of the problem.

The original expectations have been well sobered down and the question resolved itself into the endeavor to obtain a sufficient purification at the least cost to the community, instead of expecting a large profit. Not one but several methods are found to give good and economical results, and their respective advantages depend on local conditions which require careful consideration in each case.*

The last obstacle which prevented the water-carriage system from answering every hygienic and economic requirement seemed herewith to be removed. Yet there are still a number of prominent men, especially on the Continent of Europe, who are active in their endeavors to hinder its adoption, notably Dr. Alex. Müller in Berlin, Dr. van Overbeck de Meijer in Paris, and Dr. L. Winterhalter in Munich, chemists and hygienists.

In scanning their elaborate arguments, however, a marked professional bias is observable, and possible hygienic deficiencies in the water-carriage system seem to be greatly magnified, whereas important technical questions are wholly ignored or misrepresented, and, on the other hand, they have commended substitutes for these cities which for engineering or financial reasons are objectionable. Decomposition and imperfect ventilation in sewers, soil, and river pollution are judged from badly designed or old works, which modern engineers also condemn, and the best constructions are thought exceptional or are not given any consideration. On the question of sewage disposal they also magnify the defects but overlook the benefits and gains. On the other hand, essential points have often been practically ignored by municipal engineers. These should appreciate the real aim prompting such attacks and realize the dangers to which they may expose communities by improper and careless work, thus constructing new and easy means of propagating and disseminating germs of disease. The superficiality with which some sewerage works have been built often in our own country is appalling and furnishes critics with abundant material, which is frequently used against the system itself.

The present time furnishes the engineer with enough experience and facilities, as I believe from my inspection, to economically design, construct, and maintain sewerage works which can effectively satisfy the just demands of sanitarians. If this is to be the conclusion, it must, on the other hand, be based on the condition that engineers pay greater attention to these demands, and not ignore the fact that they are the *prior* claim which the works should satisfy.

Also for dwellings, where sanitary precautions are even more important than in the treets, water-closets are preferable to the best-managed dry-closets, because a much greater degree of cleanliness can be attained. Therefore, if all other governing points are equal, water-carriage should always be recommended *versus* dry removal. But the rapid and continuous flow of water-carried sewage from its entrance into the sewers to its final outfall forms the chief claim of superiority over the dry removal.

The remaining point of comparison is the cost. It has already been stated under what circumstances dry removal will be most economical, which implies to a certain extent the conditions under which sewerage is to be preferred. These can now be directly stated as follows:

1. Where a regular water supply in sufficient quantities is furnished to the dwellings, this being the most essential condition.

2. Where waste water is sufficiently abundant and foul, and therefore requires rapid removal to a distant point, which will usually follow the former condition, especially in large towns.

3. Where the population is dense, which relatively decreases the expense per inhabitant.

4. Where the topographical features and location of the town do not require an unreasonable outlay of money. Water-carriage would, for instance, not be economical in small towns, on very steep and irregular slopes, with bed-rock near the surface, or where the site is a long, narrow strip along the shore of a large river, when the expense of sewerage would be out of proportion to its benefits over the dry removal.

5. Where the disposal of sewerage offers no great difficulties or expense. It is questionable, for instance, whether sewerage could be advised for an inland town having

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* See VI. Disposal of sewage.

a very cold climate and where, from the absence of a large river, its sewerage must be purified.

6. Finally, in general, where the interest of the amount invested in sewerage will be smaller than the cost of dry removal, provided the latter is kept up to a sanitary standard. This condition will cause the advantages of water-carriage to increase with the size of the cities, but the exact point beyond which sewerage is cheaper than dry removal can only be determined from the local peculiarities.

After these remarks, applying to water-carriage in general, it is now in place to examine into the ways by which it has been effected; and here, too, we are met by a variety of opinions.

In the main there are two systems, as already mentioned, the "combined" and "separate." The latter is again subdivided, on account of different views, into the Ordinary, the Shone, and Liernur systems.

*Combined system.*—The characteristic feature of this method of sewerage is that it serves the double purpose of removing sewage and rain-water by means of the same sewers. In tracing its origin it was found that the underground removal of rain-water in densely populated cities was considered necessary even before a regular flow of sewage was created by the introduction of a regular supply of water; and at the present day, when the built-up districts are even larger and the pavements are better, which allows a more rapid concentration of rain-water in the streets, this underground removal in large cities is even more necessary.

Further, it has been found in London* that during a rain the first wash from the streets is likely to be as foul as ordinary sewage, and therefore it is proper, especially when they are not well cleaned, that it should be led into the same channels.

The combined system, therefore, consists of a net-work of sewers, having a sufficient capacity for the removal of storm-water in addition to sewage, and having inlets for its reception along the streets as well as in the houses and yards. To prevent heavy substances, such as sand, from entering the sewers and silting them up, catch-basins are attached to the inlets whenever deemed necessary. To prevent gases, caused by the decomposition of sewage, from disseminating where they could be injurious, traps are inserted near the inlets in the houses or streets. Yet to enable them to escape at proper places means of ventilation are provided by untrapped pipes terminating above the roofs, by chimneys, or stacks, and by open gratings at intervals in the roadway.

The disposal of the sewage is attained either by leading it directly into large rivers, or by means of intercepting sewers which collect the sewage alone and let the rain-water flow into the nearest water-course, carrying the former to a certain locality, where it can be purified. Access is had to the works by man-holes at convenient intervals, and appliances for flushing are attached wherever necessary.

To determine the merits of the combined system it is necessary again to examine it, first, from a sanitary point of view, and then with regard to its relative cost; and in doing so, it is premised that the works are well designed, well executed and maintained. Its sanitary advantages may be said to be as follows:

The periodical conveyance of large quantities of storm-water through the sewers has a cleansing effect, such as would be expensive to obtain artificially in even much smaller sewers. In some cities, mostly in America, this is the only means by which sewers are cleaned. However objectionable the omission of further cleaning is, it cannot be denied that storm-water flushing will always be a powerful agent to maintain the sewers in a sanitary condition, and should be made use of wherever other circumstances will permit of it. A concomitant advantage will be the removal of the dirt and filth from the surface of the roads, unless the street cleaning is otherwise efficiently attended to. In Paris it is even found preferable to wash this dirt into the sewers at ordinary times,† which enables the streets to be rapidly and well cleaned, and the transportation of the silt by the sewage, aided by the "bateaux and wagons vannes," with subsequent removal at the outlet, is but little more expensive than carting it on the surface. The large size of the sewers for rain-water removal greatly facilitates inspection and cleaning, compared with those which convey sewage alone, and also greatly decreases the possibility of an obstruction. In spite of careful precautions, substances which, theoretically, are to be excluded, will get into sewers. Grates are accidentally or willfully lifted up, and articles, such as cans, scrubbing-brushes, old clothes, and dead animals, have been introduced and subsequently removed as the cause of stoppages.

As the combined system is a single one, it facilitates the management, and, therefore, increases the probability of having proper attention given it. When two systems of sewers are found in the same street, it has often occurred that connections have been made to the wrong sewer, which partially defeated the object of the "separate system." This difficulty is stated for England in the "Suggestions of the Local Government Board," and it would be still greater in our own country, where municipal affairs are less strictly managed.

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*Analyses of street-water by Professor Way, London.

†There are no catch-basins to the street inlets in Paris.

The sanitary objections to the "combined" system, as given by the advocates of the "separate" one, are as follows:

The difference of velocity during rain storms and at ordinary times is liable to cause deposits after the storm is over, when the rapid flow is checked and the suspended particles are precipitated. The latter is also sometimes aided by a decrease of grade in consequence of a larger size of the sewer. This objection, although valid in some cases, cannot be made to rightly designed sewers. Deposits are prevented to a great extent by giving the sewers sufficient grade to allow the *ordinary* flow to move the silt which usually gets into them, and not relying on the mean velocity of the storm-water to accomplish this purpose. Deposits can also be often avoided by an egg-shaped section, in which the invert radius is about as small as the radius of a semicircular section just filled by the ordinary flow.

Another point of attack has been the slimy decomposing coating (in German, sielhaut) sometimes observed on the sides of the sewer, which is formed by the adhesion of particles floating on the rising and falling surface of the sewage. The objection is made chiefly from the anti-water-carriage stand-point, but it applies more to the combined than to the separate system, where the change in the surface of the water is not so great. This filthy coating may undoubtedly at times cause injurious emanations, yet it can practically be prevented by a regular flushing of the sewer, and also by giving the interior a smooth surface, which does not readily permit the adhesion of floating matter. A smooth surface is advisable also for other reasons, as will be seen later.

Further, it has been said that flushing cannot clean large sewers as well as small ones. This is true under certain conditions; mainly, when their designs are faulty and less care is given to their maintenance. If the cross-section of the flowing sewage is a flat segment, flushing has not the same power as when it is semicircular. An egg-shaped section, so proportioned that the invert gives to the daily flow of sewage approximately a semicircular section, will permit of the same flushing effects as a pipe of corresponding size. The only important difference then is with reference to the coating on the sides, which is more extensive in the combined sewers. The smaller pipes can be entirely filled by a much smaller quantity of water, and therefore this coating can be more readily prevented. But this advantage, though important, has yet been much overdrawn. Without greater cost large sewers can be cleaned to a degree which cannot be objected to, as many existing works, especially Frankfort and Hamburg, sufficiently prove. If the water or sewage is dammed up by penstocks and used in greater abundance, the effect is quite satisfactory. The velocity of the flushing water depends more on its head than on the difference between the sections. In smaller sewers the same quantity of water can be maintained at a greater head than in larger ones, where it sinks more rapidly.

In Paris fæces are kept out of the sewers because, it is said, they cause the offensiveness and danger of sewer air, and, as men are constantly engaged in flushing and cleaning out the silt, are therefore objectionable. But experience does not prove such an effect of fæces alone. The air in well-built sewers, with complete water carriage, is not at all offensive on this account. In the sewers of Frankfort and many other places the air is not only equal to but even better than that in the Paris sewers, where it has several times occurred, from want of sufficient ventilation, that men have been suffocated.

The question of ventilation next demands a few words. It is said that large sewers contain a greater quantity of impure air, but impurities emanate primarily from the sewage, and their quantity stands in relation to it, instead of to the air in the sewer. If the sewage is decomposing and foul, the air will be worse than when the sewage is fresh; and a certain amount of impurities arising into the air will evidently pollute it more in small and less in large sewers. It is further given as an advantage of the former that the entire air can be more readily exchanged in small sewers. Yet, as it is more foul in them, a more frequent exchange is necessary. Dr. Buchanan states* that noxious germs in small sewers produce a more intense poison than in large ones, and that small sewers need the more frequent openings for ventilation.

The impurities reaching the atmosphere from the same quantity and quality of sewage will be practically the same whether the sewer is large or small. But this supposes the inner surfaces to be tolerably clean, as they should be and are in most of the sewers that I saw in Europe. When covered with a thick film of slimy matter in perpetual decomposition, it will affect the air contained in a sewer more than the fresh sewage. Yet, also from this cause, the size itself is not necessarily objectionable. The air will even be less polluted in a large than a small sewer, other conditions equal, because its quantity increases as the square of the perimetrical surface. However, when the sewage is fresh and flowing rapidly, and the total amount of impurities generated depends more on the extent of the slimy surface, if such exists, it is evident that, irrespective of the degree of pollution, this total amount will be greater in a combined sewer. The interior surface must, therefore, be in a reasonably clean condition, if the air escaping from the two systems under like conditions shall be of like quality. That this is neither difficult nor expensive to do, was proved to me by the inspection of many rightly-designed sewers in the cities I visited.

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* Report of Medical Officer of the Privy Council, 1875, pages 47 and 48.

The ventilation of large sewers through house-pipes, it has been said, is very imperfect and uncertain. This is true when it is connected with ventilation through openings in the street. The friction in the long pipes, and the fact that matter is discharged through them in a downward direction, will greatly hinder an upward draught, whereas an opening in the street immediately permits exchange, except when covered with snow.

Objection has also been made against the combined system on account of the inlet-basins along the streets, which frequently emit odors as bad as badly-kept sewers themselves. Without entering further into the question of inlet-basins at present, it may simply be stated that if rain-water at all requires underground removal, this objection holds equally good against the separate system.

Finally, it is claimed that when purification of sewage is needed its separation from rain-water is necessary. This conclusion can only be conditionally admitted. If the storm-water, when it is but slightly mingled with sewage, is objectionable in a stream on account of the future use of the water, it will be best to keep them entirely separated. There will be more cases, however, where the conditions do not make this total separation necessary. A slightly increased bulk of sewage delivered on farms or works for purification during storms, is not always objected to if confined to the first wash off the streets, &c., which is not much cleaner than ordinary sewage. On the other hand, it is also generally permissible to let a slight amount of sewage flow into the river together with a large amount of storm-water. The size and character of the river and the use to which its water is to be put thereafter will determine the amount of sewage which can be admitted in this way, and therefore the advantage of separation. And here a usual tendency of criticism must not be overlooked. While no objection is made to a slight amount of impurities discharged into rivers from natural causes, great objection is sometimes made to the same degree of pollution when it is permitted or caused by works which were constructed to prevent a much greater degree of pollution. The storm-water which is discharged by the sewers after the first surface wash has been intercepted, will not differ materially, if at all, with regard to the amount of organic impurities it contains, from the water which enters the river from the separate rain-water sewers when they have been dry for some time, and from the surface of towns and fields after a drought.

The case, however, which needs a close inquiry in this respect, will not be the effect of sudden and heavy storms, but of light and long rains. The sewage reaching the purification grounds from a combined system will be diluted for a longer time, and the overflow from intercepting sewers will be proportionately more polluted as the intensity of the rain is less. Only the locality can furnish the deciding elements on this point.

The objections that have been made against the combined system on sanitary grounds are, therefore, only substantiated when it is imperfectly designed, built, maintained, or applied—difficulties to which the separate system is also exposed, and perhaps from its greater complexity in some cases even in a greater degree. When purification is needed it will depend on the local conditions whether the combined system with interception of sewage is to be avoided, but not on any general defect of the system itself.

If from a sanitary point of view the method of leading rain-water into the same channels with sewage is not necessarily objectionable, it only remains to inquire whether the expense of so doing is greater or less than by separation.

The great variety of conditions, topographical, physical, and social, including the cost of proper materials and labor, make it impossible to do more than to indicate their relative expense in very general terms, together with the directions in which the economy of the two systems is most distinctly seen. Nothing but a careful local estimate can in many cases decide which is less costly.

The expense of a sewerage system does not merely include its first cost, but also its annual cost for maintenance. As the latter represents the interest on a certain capital, it should be carefully considered in a comparison.

When systems are compared financially it should be done with regard to the objects they accomplish. The combined system can naturally only compete with the separate, in cases where both sewage and rain-water alike are to be provided for. The cost of Liernur's system has been advantageously compared with that of the combined, while the former did not provide for any rain-water removal either on or below the surface. The question is, which system accomplishes the same purposes at the least expense. Just as account was taken of the removal of waste water in comparing dry removal with water carriage, so must the removal of rain-water be accounted for here.

When separate sewers are built for storm-water alone and are proportioned for the same amount as a combined system, they alone will cost nearly as much as the latter. A saving of expense is obtained by less depth of excavation in many places, and consequently, also, more grade and a smaller diameter. The cost of the system for sewage alone will be additional and generally be much greater than the saving effected on the rain-water sewers, even if built in the same trench. Although nothing but a special examination will determine it, yet it can be said generally, that the cost of *two* sewers to accomplish the same object as *one*, will be greater.

To draw a general comparison regarding the cost of maintenance is more difficult. The combined system can more easily be inspected and cleaned, on account of its greater size, than the separate sewage-pipes, and if properly designed is less likely to get entirely obstructed by accumulations. Sometimes, however, it may be considered an advantage to let a slight amount of deposit obstruct the channel, and in thus giving warning cause it to be removed, while in a larger sewer it might remain unnoticed for a much longer time. The fact that there is only one set of sewers, and therefore less length to be inspected for the same area, will also reduce the cost of maintaining the combined. The expense of flushing the two systems will not vary greatly, provided both are designed and constructed equally well and cleaned in the same manner. The combined system has an additional advantage of the scouring effect of heavy rains, which, in many of our own cities, furnishes the only means by which a cleaning is effected.

From these points it can be concluded that the economy of a combined system over a separate one depends mainly on the following conditions: Where rain-water must be carried off under ground from extensive districts, and when new sewers must be built for this purpose, it will generally be cheaper. Its cost will also be favorable in densely-inhabited districts from the circumstance that the proportion of sewage to rain-water will be greater, and therefore increase the sizes of the separate sewage-pipes, yet without decreasing those of the rain-water sewers; while the sizes of the combined would not vary with the population, because the quantity of sewage is less than the quantity within which the amount of storm-water can be estimated.

But more important is the fact that in closely-built-up sections the surface washings from slight rains would carry an amount of decomposable matter into the rain-water sewers, which, when it lodges as the flow ceases, will cause a much greater storage of filth than in well-designed combined sewers which have a continuous flow, and generally, also, appliances for flushing. In cities which give every indication of rapid growth these points become of importance when deciding upon a system.

*Separate system.*—The separation of sewage from rain-water by leading them into different channels originated, as already mentioned, from causes which were mainly financial. Where existing sewers could be made use of for rain-water conveyance alone, very much smaller pipes only were necessary for sewage; and where proper and complete purification of sewage was very expensive, it was advantageous to prevent it from being occasionally increased even by a small quantity of rain washings from the surface.

The old sewers being incorporated into the new system with slight alterations and extensions, naturally reduced the cost of the entire works very materially. It was then thought, as the sewage was found to be effectually removed in the small pipes, and, on the other hand, many if not most of the large sewers showed accumulations of house filth, that the separate system had inherent merits on sanitary grounds.

Among those who are advocating the principle, there is some disagreement as to the design by which it will be best accomplished. Several systems are proposed, the distinguishing features of which are briefly described as follows:

The *ordinary separate system* as used in England consists of a pipe-line extending into each house, there to receive the house drainage, generally with an admixture of some rain-water from the yards and back buildings. The rest of the rain-water, where it cannot flow off in surface channels, is carried off through separate sewers. These may be quite shallow, as their only object is to remove the water from the surface.

The details of the former are substantially like those of the combined system. The only differences are in their shape, which is circular, on account of the regularity of flow, and their size, which is very much smaller. There are also no street inlets connected with it. The details of the rain-water system are also substantially like those of the combined, excepting their depth, and in most cases the absence of connections, except from street inlets. In shape and size there is no material variation. Manholes for inspecting are required for both lines of the system, and flushing arrangements, absolutely necessary in the sewage-pipes, may be omitted in the rain-water channels, if they are well constructed.

The object of leading some rain-water into the smaller pipes intended for sewage alone is mainly to get the advantage of an occasional heavy flush. The self-acting flush-tank, recently invented by Mr. R. Field, has been proposed as a substitute for this irregular cleansing, as well as for the flushing by human aid. It has been quite successfully applied in England, notably at Aylesbury. The necessity for introducing any rain-water into the sewage-pipes is, therefore, dispensed with in using this regular means of flushing. Experience is too limited, however, to determine the range in which it will be useful and advantageous over other modes of flushing. And it will depend on this experience whether it is wise to exclude all rain-water from the sewage-pipes or not.

*Shone system.*—A substantial variation from the ordinary separate system has recently been proposed by Mr. I. Shone, of Wrexham, for localities where sewage for one reason or another requires a frequent lifting.* Self-acting sewage ejectors are distributed over the district and operated by compressed air supplied from a central station. The sewage runs into an iron container, holding from one to two cubic yards, and is then automatically ejected and lifted to any desired height. The advantage of this class of pumps consists in lifting small quantities at any number of convenient points, so that it can continue its course each time in shallower sewers and with better gradients. The economy and convenience of compressed air for transmitting power to long distances, in comparison with steam, makes the principle a practical one.

As the system has not yet been in operation, except for trial purposes on a small scale, it is not possible to determine its future value with certainty at present.

*Liernur system.*—Another variation of the separate system, and one which has already had extensive trials, is proposed by Captain Liernur, of Holland. In its original form, it should hardly be classed under water-carriage systems, and even now the matter which it is intended to remove is rather suspended in water than carried by it. Yet the character of the sewage and the entire works themselves are so similar to what is given under this head, that an absolute distinction is not warranted.

Its origin can be traced to the cess-pool system. In several cities, notably in Paris, the closet refuse was, and still is to some extent, passed into a water-tight pit, from which it was removed at intervals in the following way: A large cylinder, from which the air has been exhausted, is placed on a cart and taken to the premises. A tube is connected with the pit, a valve opened, and the contents of the latter are forced through the tube into the cylinder by atmospheric pressure. Isolated houses not connected with Liernur's system of pipes are still treated by him in this way in Amsterdam. The uncertainty of the vacuum after reaching the dwelling or the loss of power when the contents of the pit do not fill the cylinder have made it preferable, either to exhaust the air by means of a pump on the premises as is extensively done in France, Germany, and our own country, or to lay the tube permanently under ground, from each dwelling to a common tube, and thence to an exhausted cylinder in a central position.

The latter is substantially the Liernur system. It was proposed to dry the matter by waste heat from the engine and obtain a valuable manure. The use of the water-closet and the unpreventable addition of some waste water have virtually made the sewage so dilute (50 parts water to 1 part solids) that the expense of evaporation has caused this idea to be abandoned.

The present system, as used in four or five towns in Holland, may be briefly described as follows: The excreta drop into an ordinary hopper-closet, which is ventilated from its upper edge by a pipe leading to the roof. Water is permitted for flushing, although there are restrictions as to its quantity. Under the closet is a trap from which the matter drops into a vertical soil-pipe, and then passes horizontally to the "barometrical" trap and on to the street mains. These unite in an underground iron reservoir, sufficiently large to hold the excrements from the number of buildings in connection with it, and provided with necessary stops and valves. From here a delivery-pipe leads directly to the central station where the air-pump is situated, and where the sewage is run into barges and taken away to the place of final disposal.

The "barometrical" trap is an important feature in equalizing the air pressure at the many houses and in regulating the exhausting of the sewage, the quantity of which is different in every branch. It is simply a running trap with its depth a constant quantity in every case, which enables the vacuum, created in the main, to draw the sewage from all branches until in every one there is only enough sewage left to seal the trap. The difference of water-level on its two sides then measures the pressure against the vacuum, and, if the latter be further increased, all traps would be simultaneously drawn. It is thus possible to prevent a destruction of the vacuum by one pipe becoming emptied before the rest. The operation of the system is not complicated.

The air in the various reservoirs and in the delivery-pipes connecting them with the central station is exhausted by an engine, stationed at the latter, to a vacuum of about two-thirds of an atmosphere. Then a valve connecting the reservoir with a main is opened and the contents of the latter are forced into it with very great velocity. In this way, after the air from the reservoir has again been exhausted through the delivery-pipe, a second main is emptied, and so on until the reservoir holds the sewage from the district which it serves. The delivery-pipe is again exhausted, and now the entire contents of the reservoir, on opening the valve, rush to the central station. The whole operation consumes thirty minutes, and requires but one attendant.

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* I. Shone; Scientific and Sanitary Drainage. London, 1881.

The length of a main is about 800 feet, which relieves, in Amsterdam, 80 branches for about 160 soil-pipes. The pipe lines are all iron, 5 inches in diameter, whether branch, main, or delivery; and experience has shown that they remain air-tight, and that no permanent coating decreases their capacity. The system has been in use since 1871.

As far as described no provision has been made for the removal of any substances but the excreta and toilet-water. All other waste fluids from houses, factories, and streets, together with rain-water, are to be led into another system of underground pipes, like ordinary sewers. Although this has not yet been executed, nor is it contemplated, it will be easy to see that the design and extent of these sewers cannot differ materially from the combined system itself. At present the rain and waste water run partly over the surface and partly through old sewers into the numerous canals and water-courses peculiar to the towns in Holland.

I will now enumerate the sanitary aspects of these separate systems and examine into their relative cost, and in doing so it is best to first consider the general question of separating the sewage from rain-water, and then the special designs.

The main advantage claimed for the separate system is for the case when purification of the sewage becomes necessary before entering the streams, because the sewage is kept more uniform in quantity and quality. It is maintained both that storm-water should not be polluted by city filth, and that sewage should be kept free from rain.

Regarding the two latter points, opinions differ among the advocates of the separate system itself as to their relative importance. Monson insists on the former, in order to preserve the purity of the rivers, and considers the latter of minor importance, if kept within reasonable bounds. Waring insists upon the latter, but considers the former less important. These questions have already been partially considered under the combined system, and they may now be briefly answered to the effect that when the streams cannot bear the introduction of any polluted storm-water running off from the surface of the town, then a preservation of its purity will need most attention, and the dilution of the sewage is secondary in importance. When purification of the sewage is difficult, and often when pumping is required, then only is a restriction to its dilution by rain-water of more importance.

From these cases it will be seen that the advantages claimed for the separating system, as such, are based on the conditions of the locality requiring drainage.

Objections to the separation of rain-water and sewage, some of which have already been mentioned while considering the combined system, are as follows:

Small pipes increase the possibility of stoppage and disorder; slight and almost unavoidable imperfections at their joints, either original or from settlements, being mainly the cause. Wherever small pipes have been used these obstructions have occurred, and when they occur are more difficult to remove. In general, small sewers are more troublesome to inspect and to clean.

Although ground for these objections exists, they are mainly based on cases when the sewers have either been improperly built, with regard to design or workmanship, or carelessly maintained by neglecting inspection or flushing. The enormous extent to which pipe-sewers have already been successfully used, particularly in England, shows that the above objections cannot be made to small pipes as a principle, but only to imperfect management.

Regarding the double system, it has been objected that if not absolutely tight the pipes will act on each other under the street and so defeat the object of separation. Connecting houses with the wrong sewer has done the same. But such objections are based on imperfect work and imperfect supervision, both of which may have as troublesome consequences in the combined system.

The channels receiving the rain-water alone are said to be about as foul as ordinary sewers, and if this is the case separate sewers are hardly justifiable. This objection is only valid when the sewers have comparatively flat bottoms, when the streets are not well cleaned and much filth is washed underground and left to decompose. Good construction and maintenance will avoid the objection. But without this care my inspection has convinced me that separate rain-water channels, receiving the surface drainage of streets and the filthy accumulations of catch-basins, differ little from combined sewers. And if they are to answer sanitary requirements equally well, they can also not differ much in design.

The extent of the surface from which rain-water is to run, either into the sewage-pipes, the separate channels, or to remain on the surface, is differently advocated. Some sewage-pipes receive no rain-water at all, some only that from the back roofs.

Some, in addition to this, receive the water from the back yards, possibly in places making up nearly the entire block, or about one-half of the built-up area, allowing the other half, mainly from the streets, and which is as polluted as the water from roofs and back yards, to run into the rain-water channels. The disadvantage of this feature, unless the latter are carefully looked after, is apparent.

To prevent the street-wash from fouling the separate sewers, and to use it for flushing the streets during storms, and also to reduce the size of the sewers, it has been proposed to keep it on the surface as much as possible, if not altogether, and to let only the rain-water from the blocks enter them, which, as the latter furnishes much less cause for fouling them, is undoubtedly an advantage. But, in comparing the cost, it must be considered that the expense saved in keeping the street-wash on the surface must be proportionately applied to the combined system, where this can also be done, although from a sanitary point of view it signifies nothing to turn the street-wash into a sewer where already much greater impurities are being conveyed.

It appears, therefore, that neither are the objections to separation serious nor the advantages great, except in certain cases where purification is difficult and the pollution of rivers feared.

Regarding now the comparative cost, the separate system is said by its advocates, especially those claiming patents, to be much cheaper. When rain-water can as conveniently and safely be led off on the surface, there is no need for the combined system; and its cost, mainly due to storm-water removal, should not be compared with that of only a part of the separate system. The general question of comparative cost, with this view, has already been considered. It is therefore only necessary to restate the main points briefly, and to add such as were not mentioned before.

When sewage requires pumping it adds a certain permanent expense, which varies partly with the amount of sewage to be lifted. It is therefore economical to reduce this quantity as much as possible, especially when the lift is a high one; and in this case the separate system, which excludes the storm-water, may become preferable on this account.

When storm-water can be led into old existing channels which are unsuitable for the conveyance of sewage, but which can be repaired and sufficiently extended at no great cost, it is evident that the expense of constructing new sewers for sewage alone will be much less than if a new combined system were built.

When it is necessary to build a system of sewers for house drainage, with the least possible delay and cost, the separate system will likewise be more economical, if the rain-water removal is not a pressing question and can be postponed to a future day.

When rain-water can be led off in a few valley-line sewers, it will sometimes be more economical to keep it separate, by leading it into shallow channels, thus saving excavation and often getting a better grade to the outfall; or, the rain-water alone, after leaving the central parts of the town, may then continue its course even in open channels. In small towns the latter is often possible.

When all the rain-water can flow off on the surface of the town without inconveniencing traffic or flooding cellars, it is not necessary, of course, to lead it off underground in expensive channels. A combined system then reduces itself naturally to a separate one, which becomes the most economical.

A duplicate system for a large, closely-built-up area, where the rain-water sewers require to be equal in extent and size to the combined system itself, has never yet been carried out, although occasionally advocated on sanitary grounds. That the cost of such a system would be greater under otherwise equal conditions seems beyond a doubt.

A second set of private drains for each house is expensive and could not well be enforced in poorer quarters. From small premises the rain-water could always run over the surface until it gets on the street. In fact, it would hardly ever cause trouble, if the rain-water falling on each block, which virtually is a summit, and where a large quantity of water cannot accumulate, would run on the surface to the street, and from there be led underground.

A few general comparisons with reference to the cost of maintenance have already been given, and it was concluded that inspection and cleaning were more readily accomplished in the combined system, but that it may be considered an advantage of small pipes that they give an early warning of accumulations which can remain unnoticed in a large sewer for a much longer time. It was also said, as there was less length to be inspected for the same area in the combined sewer, that the cost would be less; but it must be added that this will only be the case when the same amount of rain-water is removed subterraneously in both cases. To properly maintain a pipe-sewer alone will generally not cost more than nor even as much per linear foot as a large sewer discharging the same amount of sewage.

The principle of separation, therefore, although often ostensibly preferred on sanitary grounds, does not necessarily give the system in this respect any decided advantage over the combined, except under certain definite conditions. Under all others, preference will depend on the cost both of construction and maintenance, which only a careful estimate, based on the local requirements, can determine.

After having reached this general conclusion, it will now be necessary to examine into the special designs and to state their several advantages and disadvantages, both with reference to the combined system and to each other, as far as pertinent to the question.

The *ordinary separate system* is the most extensively used and advocated among those under this head; and its special sanitary advantages (some of which have already been alluded to under the objections to the combined system) are claimed to be as follows:

The pipes conveying the sewage alone can, from their smaller size and better grades, be more thoroughly flushed, and therefore contain less deposits and no extensive slimy coating. In short, they can be kept cleaner. The flow is more regular and the velocity more uniform, which makes it less likely to deposit heavy silt, as in the great change of velocity during and after a storm. Small sewers are more readily filled by a flushing stream, and this can usually receive a greater head for the same amount of water, both of which very much increase its cleansing effect. These points, among others, are brought out prominently by the advocates of the separate system in arguments to show its great superiority over the combined. A closer examination, however, will show that the results obtainable are in some points only slightly better and in others not necessarily so. A bias is here undoubtedly observable. The fact that there are direct personal interests concerned in several of the systems brings them out more prominently, and it is also observable that those who advocate them exclusively are generally not concerned in directing, managing, nor are always thoroughly familiar with the engineering questions in a large and populous city. The advocates of the separate system usually ignore the practical possibility of making large sewers as perfect sewage-carriers as small ones, basing their opinions on perfect works in this case and imperfect ones in the other.

An actual and extensive inspection cannot but reveal the fact that the above points give only slight advantages, if at all noticeable, over properly designed and constructed combined systems, and also that the latter can readily be kept as well cleaned as is necessary.

This can be particularly noticed in Frankfort, Hamburg, and the newer sewers of London, Liverpool, and other English cities, in which the air before and during flushing was not found to be very offensive—no more so than in Reading, Oxford, and other towns using the separate pipes.

The removal of any heavy silt, deposited by storms, can in almost all cases be effected by regular flushing. If the sectional shape of a combined sewer is such that the ordinary sewage can flow in a semi-circular channel equal to that given to it in a separate sewer, the advantage of the latter will greatly diminish. By an egg-shaped form, in which the invert radius is not larger than that of the pipe sewer, this condition is approximately reached, and the egg-shaped sections should be so designed.

The advantages claimed for better flushing are partially for the same reason not much greater. The scouring effect in the same semi-circular channel cannot be very different. Flushing under a greater head in one case is nearly equaled by the facility of penning up a greater quantity of sewage with which to flush in the other.

The reduction of the area covered with a slimy coating, as compared with larger sewers, is an advantage of small ones which can be met in the former by smooth surfaces and extensive flushing.

The absence of great changes in velocity caused by storms, and hence of heavy silt deposits, is also given as an advantage of the separate system, which, however, can also be met by more powerful flushing in the combined.

It is further claimed that the ventilation in small sewers can be more thorough than in large ones. While considering objections to the combined system, this question was examined, and it was found that the impurities reaching the atmosphere from one system will be practically the same as from the other if both are well maintained, yet with the odds against the combined. It may here be added that the friction of air will be greater in smaller pipes, by which the circulation is relatively impaired. The downward motion of the water will tend to draw the air downward, whereas warmer air in the higher portions or in the house pipes will tend to draw it upward.

The assertion that house pipes will better ventilate a small than a large sewer is only true when no other means are provided. Openings in the street will offer less resistance to an exchange of air than long house pipes, and therefore will effect it first.

As the circulation of air in a large sewer depends on its relative temperature and pressure, it is evident that its bulk is not as readily replaced as in small sewers, where the flow of sewage in the warm seasons also facilitates this exchange. Therefore as the total quantity of air in a large sewer contains as many impurities as the air in a small sewer under normal conditions, they can be more readily removed in the latter, although not diminished in quantity.

A claim that the separate system will reduce the death-rate more than the combined has not yet been substantiated. If it is difficult to trace the direct influence of sewage works in general on reducing the death-rate, on account of the numerous other influences, it is still more difficult to trace a difference in the influence of either system. Philadelphia, which has a very inferior system of sewerage, has a death-rate of about twenty. In New York, where it is much better, the death-rate is twenty-six, and in Memphis, where the sewerage is still better, the death-rate is about forty.

The unfavorable criticisms against the ordinary separate system can be summed up as follows:

Unless there is a water supply abundant in quantity, constantly available, and under pressure in every dwelling, the separate system will be much more liable to give trouble by stoppages than the combined. Although this is true, yet it is not serious as far as short stoppages of the regular water-supply are concerned, as the trouble arising therefrom would be mainly in the house pipes, which would not materially differ in both systems. Where the water-supply is scant and uncertain both systems are alike objectionable.

It is a matter of fact that, although great care has been taken to prevent large matters from entering pipes and forming a nucleus for a serious obstruction, an abundance of instances have occurred where such matters have been taken out. A theoretical supposition that they cannot enter must give way to the practical fact that they do enter, if within the bounds of possibility. This objection can be made unimportant by the adoption of the Rawlinson principle of having straight sewers, both as to line and grade, between every two adjoining points of access. By this means obstructions can be more easily located, their nature ascertained, and a removal effected.

To build straight lines is not necessarily costly, and man-holes and lamp-holes can as well be put at bends as between them. The assertion that changes of direction, especially in small pipes, must be by gradual curves and not by angles is misleading and partially incorrect. The resistance of curves can be fully compensated by an additional fall. If at a man-hole the necessary extra slope can be obtained, curves of a few feet radius in order to avoid eddies are sufficient. The entire curve is thus in the man-hole, which will enable the rest of the line to be perfectly straight and capable of being looked through.

That man-holes generally fail of this use, and that a thorough inspection of very small pipes in this way is not possible, which has been said by opponents of the separate system, can be answered by making a very perfect alignment and the man-holes large enough to permit of a crouching position of the attendant. I have heard it stated sufficiently often by workmen as well as engineers in England and in Germany, that there was no practical trouble in ascertaining the nature of an obstruction in this way, and also in removing it, both of which could not be done as rapidly nor as well without the man-holes and straight lines.

It is a question, however, whether the expense of man-holes for this purpose is always justified, when they do not also serve as ventilators. The occurrence of obstructions which cannot be removed by ordinary flushing is comparatively rare in well-managed systems, and it may be more economical to break into the street on such occasions. The latter may not be objectionable in small towns; but in well-paved streets and closely-populated districts with considerable traffic the annoyance and the expense of tearing up and repairing the street may be equivalent to the cost of a man-hole or lamp-hole each time, not to speak of the difficulty in properly repairing pipe-sewers. Even though the maintenance in large cities is usually more perfect than in small ones, the value of man-holes does not seem to be less.

A duplicate system of sewers further brings with it the objection already mentioned, that wrong connections can easily be made. This trouble has often occurred in England, and would be still greater here. The disadvantages finally of separate rain-water channels have also been alluded to.

The special features which affect the *cost* of the ordinary separate system in distinction to the rest, are, after what has been said on its general features, reduced to the question of how much rain-water, if any, shall be admitted into the sewage-pipes.

Entire separation has been designed, for instance, in Oxford, for detached houses, churches, for the numerous colleges, and other public buildings. Although it was desirable to extend it to the remaining part of the town, yet there was a practical obstacle in the fact that most of the continuous rows of houses were already provided with single drainage, which admitted both sewage and rain. For the rest of the town the rain falling on the back roofs and yards, amounting to about one-twentieth of the entire area, was admitted.

It is readily seen that a slight variation in the quantity of rain will have a greater effect on increasing the cost of the small pipes than of the large ones. Entire separation would, therefore, be preferable to a partial mixture in small pipes, unless the flushing effect of this small quantity of rain-water is desirable.

To lead the rain-water of the entire block into the sewage-pipes would be an approach to the combined system, as its area averages in round numbers about two-thirds of the whole, the streets occupying the remaining third.

The expense of flushing and cleaning the sewage-pipes will be about the same as in the combined system, if the latter is well attended to. In the former the flushing will have to be very regular, as no reliance can be had on the cleansing effect of storm-water. The closer attention, the more difficult removal of deposits, and the absence of rain-water cleansing in the one, is balanced by the removal of heavier deposits, and a more powerful flushing necessary in the other.

The advantages of the *Shone system*, which are peculiar to it and distinguish it from the other separate systems, rest in the circumstance that the grade, and therefore the velocity of the sewage, can be conveniently increased to any desirable extent independently of the general grade of the surface. Where the velocity of the sewage would naturally be very slow, and the deposits therefore large, it may be well suited, because in increasing the grade it prevents the effects of decomposition resulting both from greater deposits and from the greater age of the sewage itself.

Objections to the system on account of the intermittent flow in the pipes, which allows particles to "strand" after the flush has ceased, might be serious if the intervals were very long. From the small size of the ejectors this will hardly ever be the case, and in comparison with the results of flushing in other systems the objection is not important.

As the cost is greatly affected by the depth of the sewers, especially in different excavations, it can be considerably lightened by this method. Yet the greater expense due to the ejectors, to the tubes distributing the compressed air, and to the principle of pumping with air transmitted to a distance, as against the direct and immediate application of power, may quite balance it, which, however, only a local inquiry can determine. The cost of maintenance is still more difficult to predetermine without a full knowledge of the locality. The greater complexity and nature of the works for pumping will probably increase it. But even considering this increase, other advantages gained may still compensate for it.

Concerning the *Liernur system* it is possible to state more definite conclusions, as a greater experience and knowledge has been gained regarding it.

The advantages claimed for this system over all others are based more on sanitary grounds than on the cost. The impossibility of any gases or germs escaping into the street, which cannot be avoided in other sewers from changes of water level and temperature, gives it a great advantage, unless the latter are so well designed and maintained as to make such an escape practically insignificant and, in comparison with other sources of impure air, also unimportant.

Another advantage given is the fact that the sewage cannot possibly penetrate the soil. The same can, however, be obtained by a careful construction of ordinary sewers, as these can be readily made water-tight under competent supervision.

The system has been extensively tried only in Holland, in flat and low sections which are intersected by water channels. It is peculiarly applicable under those conditions because it works independently of grade. At present the system is being extended in Amsterdam in the way of centralizing several scattered districts. Its actual introduction has altogether been confined to very small areas.

The objectionable features which can be placed against the claimed advantages are as follows: As the use of water in the closets is limited, and by a heavy tax made impossible for the poorer classes, the system does not permit of the same cleanliness as regular water-closets, although I found that with care they were not offensive.

Kitchen, house, and factory waste water, together with the street-wash from rainstorms, is to be led off by other sewers, which, therefore, alone could differ very little in design and cost from the ordinary combined system, instead of being like simple rain-water channels in the ordinary separate system. Liernur holds that owners of factories should be compelled to purify their own waste water if it becomes obnoxious in the sewers, but this demand is evidently not practicable, and sewers are precisely intended to avoid any such necessity. The inlet and catch basins he proposes, as well as his rain-water injectors, would be equally applicable to the ordinary system. They are, however, more theoretical speculations than practicable, and have nowhere been adopted. This entire branch of the Liernur system has never yet been carried out.

The cost of construction and maintenance as usually given, therefore, refers only to the removal of a small portion of the matter usually carried away by sewers, and it must be so compared. The 5-inch iron pipes, one on each side of every street, and the delivery-pipes, as well as the reservoirs and the central station, are expensive to construct, and cannot be as durable either as vitrified pipes or masonry.

The maintenance of the system will also cost more than that of any other, if only for the reason that the motion of the liquid, which is as fluid as any common sewage, is produced by artificial power instead of by gravity, even where this is possible on a down grade. On the other hand, it can be said that the contents of the Liernur pipes are more valuable for fertilization than ordinary sewage, because there is less dilution and admixture with valueless ingredients. As this advantage was intended to make up for the loss by an increased expenditure, it has been carefully upheld, but the dilution of the sewage has now become so great that the original idea of drying it into poudrette, and thus realizing a considerable return, is entirely out of the question. The sale of the sewage does not always pay for its transportation from the pumps.

On the whole it is evident that the advantages of Liernur's system over others will be confined to very peculiar local conditions. Where in addition to the system of iron pipes there must also be one practically equivalent to the combined system itself, all advantages are obscured by the greatly increased cost.

*Conclusions.*—From the foregoing remarks, and mainly from the advantages and disadvantages claimed by the advocates and opponents of the various systems as they were stated to me, and to which I have given such relative importance and criticism as my own inspection and examination of the works has warranted, several conclusions can now be drawn.

The sanitary demands upon a system of sewerage, it is agreed, consist in the prevention of decomposition to the greatest possible extent, and, where the latter is unavoidable, to decrease its injurious effects to a minimum. This object can be best obtained by a rapid, steady, and complete removal of all decomposable matter entering the works in a fluid or suspended state, such as either causes or is co-existent with the development of germs; and also by the removal of bulky solids which occasionally enter them and obstruct the flow, and a provision for the safe escape of vitiated air.

It can be concluded, from what has been said, that these demands are fulfilled within satisfactory limits by each one of the mentioned systems, provided they are designed and built in as perfect a manner as possible, according to the principles known to facilitate such removal and to prevent any evil effects which may arise from unpreventable imperfections. A superiority of one system over another in this respect will then not depend on its specific principle as much as on the conditions of the locality where it is applied and on the care given to its maintenance. A misapplication on one hand and neglect on the other will have a much greater influence on the sanitary condition of each single system than the difference between any two systems can have under equally good conditions.

The factor, therefore, which will mainly govern a preference is less the sanitary value, as frequently asserted, than the cost of construction and maintenance. But as also the cost depends on the locality, on its physical features, on social requirements, and on the value of ground and materials, it is evident that the criterion for judging the relative advantages of the different systems, both from a sanitary and financial point of view, is the locality itself. And as the conditions presented by the various cities and places are exceedingly different, not one particular system will be the best for all localities, but different external conditions will demand as radically different solutions, both in general and detail.

This is, in my opinion, the direction in which an ultimate agreement to the various controversies, as mentioned at the outset, may be found. And as most of the objectionable features, which have caused adverse criticism, were due to faulty construction or neglect of maintenance rather than to an essential error in the system, attention to these two subjects is at present of most importance, and will also contribute toward a greater unanimity of opinion.

It now remains to recapitulate the principal local conditions under which each of the water carriage systems seemed to be best applicable, as far as it is possible to judge from a general point of view. In some cases it may require the closest local examination, however, to determine a preference.

The *combined system* is suitable—

Where rain-water must be carried off underground from extensive districts, especially when they are closely built up, as in large cities, and where new sewers must be built for this purpose.

Where purification is not required or is not difficult and storm-water overflows are not objectionable in polluting the streams.

Where a sufficient amount of water or sewage is available for flushing the larger sewers.

The best examples were found in Frankfort, London, Hamburg, Brighton, Liverpool, Berlin, and other towns.

The *separate system* is suitable—

Where rain-water does not require extensive underground removal, and can be concentrated in a few channels slightly below the surface, or where it can safely be made to flow off entirely on the surface. Such conditions are found in rural districts where the population is scattered, on small or at least short drainage areas, and on steep slopes or side hills.

Where an existing system of old sewers, which cannot be made available for the proper conveyance of sewage, can yet be used for storm-water removal.

Where purification is expensive, and where the river or creek is so small that even diluted sewage from storm-water overflows would become objectionable, especially

When the water is to be used for domestic purposes at no great distance below the town.

Where pumping of the sewage is found too expensive to admit of the increased quantity from intercepting sewers during rains, which can occur in very low and flat districts.

Where it is necessary to build a system of sewers for house drainage with the least cost and delay, and the underground rain-water removal, if at all necessary, can be postponed.

Under such conditions the ordinary separate system can generally be applicable, yet certain special features of the locality may determine in favor of Shone's system; for instance:

Where pumping of the sewage to moderate elevations is advantageous or required at several or numerous points not greatly distant from each other, in order to increase the grade and velocity between them.

Where deep excavation is very expensive, either from being under the level of subsoil water or in rock, and where shallower sewers with better grades and intermediate lifts could be substituted, as in undulating grounds with rock near the surface when the sewage is to be carried across the ridges, or in low-lying and very flat districts with excavations under water.

Finally, in mentioning the applicability of Liernur's system, it must be added that it is extremely doubtful whether it can compete with the other systems in any locality. The most favorable conditions are:

Where the district is flat and low-lying, where a sufficient gradient cannot be had for a gravity flow, and where ordinary sewers are for some reason or other not expedient.

Good examples of the ordinary separate system are found at Oxford, Reading, Tottenham, and other small English towns. The best work on the Liernur plan are at Amsterdam. The Shone system has not yet been applied, except at Wrexham for trial purposes.

In conclusion it may be said that as quite different conditions may occur in the same town, it is possible and practicable to adopt several systems for it. It may be found expedient to exclude rain-water from certain areas, whereas the combined system would be advisable in others.

## III. DESIGNS AND CONSTRUCTION OF SEWERAGE WORKS.

One of the principal causes of the imperfections in sewerage works which have given rise to so much controversy can be traced, as we have seen, to improper designs or construction. It will, therefore, now be in place to indicate some of the general principles governing them which an inspection has shown to be essential.

A reason for such improper designs may be found, perhaps, in the circumstance that engineers did not fully consider the sanitary elements in the case. Sewerage works were frequently built like any other work, simply with reference to stability, and to satisfy the main laws of hydraulics.

The unfortunate fact that sewers are hidden from general observation, so that their action and state cannot readily be noticed without an effort, and often not an agreeable one, has also contributed to delay the general recognition of any other demands upon a system than purely engineering ones.

A special branch of engineering, devoted to sanitary works, has therefore lately developed, and we find that the best works in Europe have been built by specialists, such as Lindley, Mansergh, Latham, and others,

None but the combined and ordinary separate water-carriage systems will in the following be considered, as they are of the most importance.

### 1. *Alignment.*

The proper alignment of sewerage works, besides being governed by the topography, may also be governed by the manner in which the sewage is to be disposed of.

Three cases can be distinguished; *a*, the sewage is to be discharged into a large river near its mouth, into an estuary, or into the ocean; *b*, the sewage is to undergo eventful purification or disposal below the town, within a time which would influence present construction; and, *c*, the sewage is to be immediately disposed of at a certain point outside of the town. It is evident that these conditions may greatly modify the design.

If the city lies on the banks of a large body of rapidly changing water, as do Liverpool and Hamburg, the sewage may, if not proportionally too great, be led into it at any point without serious sanitary objections. Should deposits of filth occur, it will generally be cheaper to dredge them occasionally than to build an intercepting sewer along the banks. The alignment of the sewers can in this case be adjusted

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independently of any other considerations than those of the natural drainage-area to which they belong (Fig. 1, Plate VIII).

When, however, there is a prospect of serious pollution at a future time, several other considerations become necessary. As an interception of the sewage will then be the cheapest solution of the problem, the design should be made with this end in view, by giving the various points of future interception suitable positions and elevations in advance. Sewers too often have a wasteful descent into the low grounds, which brings the intercepting sewers below the subsoil water, adds to the height of pumping, and by a deceased grade necessitates a larger diameter, all of which greatly increases the expense.

When, finally, the sewage of a town must at once be prevented from getting into the water-course, the design will be effected still more essentially. The alignment depends, of course, on local conditions, yet there are several general features which it may be well to consider.

As the quantity of rain-water greatly exceeds that of the sewage, and, therefore, mainly influences size and cost, we must remove it by the shortest length of sewer, unless it can flow off on the surface. The sewage, on the other hand, is to have a different point of destination, either near the river below the town or in quite an opposite direction; or it may require to be pumped, entirely or partly. Therefore, it is necessary either to keep them separated from the start, or to separate them at certain points.

In the first case the alignment of the sewers proper will be governed by the topography and place of disposal; the rain-water sewers, if there are any, will follow the natural slopes and valleys.

The second case admits of several variations; often a single intercepting sewer for sewage alone built along the shore will answer the purpose. Examples of this are found in Paris, London, and many other cities. Two features, however, may sometimes make this objectionable. The upper end (at *a*, Fig. 2, Pl. VIII), being usually rather low to begin with, brings great lengths beneath the surface of the river and subsoil water, which greatly adds to the expense.

When the area is very extensive, or the ground slopes unevenly, it is preferable to intercept the sewage along several lines, as in Fig. 3, London, Paris, and Frankfort being examples.

One of them should run near the contour, from above which sewage can flow to the outfall by gravity, as *g g*; the one below collects whatever requires pumping, as *p p*. The territory above the gravity sewer may sometimes be advantageously divided into zones, from each of which the sewage can be separately intercepted, as stated before. This will prevent the sewage from becoming too much diluted during heavy storms, before it is intercepted, and bring it more quickly to the outfall. It may also, in uneven territory, prevent sudden accumulations of storm-water in the valleys.

A third type (Fig. 4) is the so-called "radial" system, as designed in Berlin. It consists of several independent districts, the sewage from each being collected at a single point, *a*, from which the rain-water is led by an overflow into the river, and the sewage proper is raised by pumps into a collecting sewer, *p*, under pressure, which carries it away from the river to the sewage farm. This system is applicable where the ground is so flat and low that the net-work of sewers, in order to gain grade, must form several artificial basins, from the lowest points of which the sewage can be pumped into a common collector.

Finally, a combination of these principles of alignment is often possible and advisable in the same town. In Paris an intercepting sewer in the northeastern district takes the sewage and rain-water from the foot of the higher grounds to St. Denis, thus preventing an undue accumulation of water in the more level parts of the city. Besides this one, several lines of intercepting sewers on each side of the river act partly as collectors.

In Liverpool some of the main sewers act as interceptors at the foot of slopes, and further on in their course as valley-line sewers.

After these more special considerations, due to the manner in which the sewage is to be disposed of, we will now allude to a few more general points applicable to all systems.

Pipe sewers which are too small to be entered are best aligned according to the "Rawlinson principle," so that they can be completely under control. To effect this the lines must be perfectly straight between two points of access, and must have a man or lamp hole at every bend or change of gradient, the latter taking place entirely within the man-hole. With this precaution carefully carried out in many towns, much trouble from stoppage has been avoided. The principal has been carefully considered in most English towns, also in Berlin and Danzig.

When sewers are sufficiently large to be entered, it is not necessary to have access from above to every point of deviation from a straight line. Instead of short curves in the man-holes, with corresponding loss of head, it is then better to have long and easy curves.

Further, the sewers should take the shortest way to a point of discharge. For instance, if *a* and *b* in Fig. 5 are two such points, it is more expedient to build two sewers, *c a* and *c b*, than one from *d* to *a*. The single sewer would not only have less grade, or else require deeper cutting at its lower end, but it would require a section from *c* to *a* much larger than in the other case.

Another point of importance may be gained by considering that a sewer of *x* times the capacity of another will not cost *x* times the money. It will, therefore, be economical to lead as many sewers together into mains as possible. In figures 6 and 7 this feature is illustrated, the point Q indicating either the outfall or a junction with a larger main. The length of the sewers is the same for each case, but Fig. 6 will be a cheaper alignment than Fig. 7. Concommitant advantages are found in the circumstance that the smaller sewers or branches have better gradients. Starting with the same elevation at Q in each case, the points *a* and *b* of the mains will be lower in Fig. 6, because the greater the bulk of water the less fall is necessary to produce a certain velocity, and therefore a better gradient can be obtained for the branches.

Still another principle may be mentioned. In case of sudden heavy showers on a greatly inclined surface which changes to a level below, the sewers on the latter will become unduly charged, because a greater percentage flows off from a steeper slope in a certain time. To avoid this uneven reception, the alignment should as much as possible be so arranged as to prevent heavy grades on the sloping ground at the expense of light ones on the levels. In other words, the velocity should be equalized as much as possible in the two districts. This will retain the water on the slopes and increase its discharge from the flat grounds, thus corresponding more to the conditions implied by the ordinary way of calculating the capacity of sewers. It will therefore become necessary not to select the shortest line to the low ground, but, like a railroad descending a hill, a longer distance to be governed by the gradient. This does not necessarily imply a greater length of sewers for the town, because more than one sewer for every street is not required by it. Equalization of velocity has, moreover, the advantage that deposits are less likely to occur—a fact which should likewise be kept in view.

Mr. Lindley, of Frankfort, has adopted a general principle of alignment which must be mentioned here. He consistently avoids "dead ends," and so does away with many troublesome points. Instead of allowing the branches to terminate abruptly, he bends each one upwards, as it were, and unites it with the sewer immediately above it, about as shown in principle by Fig. 8.* By this means the numerous dead ends are reduced to a minimum, and it is possible to flush a branch with sewage from the main above it. A disadvantage accompanying this system is a loss of grade to the former, but the possibility of a very powerful flushing at any moment will mostly outweigh it. At the very highest points of the system, as at *a*, water for flushing is obtained from subsoil drainage or the town water-supply. Penstocks, gates, or flaps at the head of each branch add expense; yet it may often be less than that resulting from the use of other methods of overcoming the troubles arising from "dead ends," such as flushing shafts or tanks; or it may be balanced by the greater advantages obtained.

### 2. *Size, shape, gradients, and construction.*

*a. Size.*—The question of size is one of great importance, not only because it materially affects the cost of the sewer, but also its efficiency. When a sewer is smaller than a certain limit, it is liable either not to carry off the sewage at all, or to become obstructed by bulky matter, and when it is too large it offers a greater surface for the adhesion, growth, or deposit of objectionable matter. Experience has caused engineers to be careful in both directions. The smaller sizes for common sewers now used in Europe are eight or nine inches in diameter, smaller ones having been found unsatisfactory and are generally abandoned. (Mansergh.) Up to diameters of 18 or 20 inches, sewers of vitrified pipe are used; beyond this there is a sudden increase to a size large enough to be entered, and then the increase is regulated according to one of the various formulæ in use and according to various allowances for rainfall.

When sewage alone is to be conveyed, its quantity determines the size. It is customary for this purpose to assume the amount of the sewage to equal that of the water-supply to the town, and in practice, when the sewers do not drain subsoil water, this is found to be nearly true. It has further been determined that one-half of the daily quantity is discharged from six to nine hours in different places. This consideration, according to local customs and the distance from the center of the town, furnishes the amount to be expected in a sewer per second, and for safety it has been assumed that it should fill the sewer only one-half, as in Reading and other places, where the separate system is in use.

When rain-water is to be conveyed in addition to the sewage, we find a great variety

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* See also detailed plan of Frankfort, Pl. VII.

of customs regarding the amount deemed proper to provide for, which results from our comparative ignorance of the value of some of the factors coming into play. These factors are as follows:

1. The greatest intensity of a rainfall and its duration, or, in other words, the greatest amount of rain falling in a short space of time and the length of time a heavy fall continues. (See Appendix No. 2.) The ordinary records give the rainfall between the hours of the daily observations. Sometimes phenomenal showers are recorded as having lasted so many minutes or hours, during a large part of which time they may have been light and during the remainder exceedingly heavy. In rare instances only have self-registering rain-gauges been used that have indicated, for instance by a curve, the intensity of the entire shower each moment, or, at most, every few minutes; and this information is precisely what is of importance for sewerage works, which are to provide for the uninterrupted removal of all of the water. In only two towns, Zurich and Munich, did I observe rain-gauges of this nature, and these had only recently been placed.

2. The relation of the quantity of water falling to the quantity reaching the sewers. On this point, also, the observations are few and not yet satisfactory, because of the several conditions to be considered. These are: *a*, the amount of water soaking into the ground depending on the porosity of the surface; *b*, the amount evaporating from the surface depending on the temperature of the ground and air and on the duration of the storm; *c*, the physical character of the surface, whether it be comparatively smooth, like roofs and pavements, or rough, like gardens, meadows, and farm-lands, or, finally, whether it be very retentive, as in wooded country or forests; and, *d*, the slope of the territory, which causes more or less rapid accumulation of the water at the low points.

Observations covering all these conditions have not yet been made; at least, not collected and made available for general use.

Some time ago* I suggested a formula, which was intended as a guide in this matter showing in what directions the observations are most needed and in what way they will affect the ultimate discharge of water from a rain-storm. Sufficient observations, however, have not yet been obtained to determine the value of the coefficients. While in Europe I received a formula from a Swiss engineer, Mr. Bürkli-Ziegler,† aiming at a similar object and having no unknown coefficients. Regarding it as the best available one at this day for approximating the amount of rain-water likely to reach a sewer, I will give it here:

| Metric measure. | English measure.‡ |
|---|---|
| $Q = c\,r\,\sqrt[4]{\frac{S}{A}}$ | $Q_1 = c_1\,r_1\,\sqrt[4]{\frac{S}{A_1}}$ |

Where $Q$ ($Q_1$) = Water reaching sewers in liters per hectare and second (cubic feet per acre per second.)

$c$ ($c_1$) = Coefficient ranging from 0.25 to .60 (.31 to .75) and depending on the nature of the surface, the higher coefficient being for paved streets and roofs, the lower one for rural sections of suburbs. Average recommended is .50 (.62).

$r$ ($r_1$) = Average intensity of rain during the period of the heaviest fall, in liters per hectare per second (cubic feet per acre per second). The amounts ascertained for Central Europe were found to be at the rate of from 1¾ to 2¾ per hour.

$S$ = General grade of area per thousand.

$A$ ($A_1$) = Area drained in hectares (acres).

The tendency of this formula is to give amounts which increase as the rain becomes heavier, as the slope increases, and as the surface becomes less penetrable by the water. On the other hand, it decreases as the area becomes larger.

The only formula which has been used heretofore, and which has a similar tendency, is the one known as "Hawksley's." §

The formulæ ‖ used for obtaining the velocity of water flowing in sewers are Eytelwein's in London, Berlin, Hamburg, and Liverpool, Prony's in Paris, Darcy & Bazin's in Vienna, Lindley's in Frankfort. When properly applied within the range of experience from which they were compiled, all give very similar results.

*b*. *Shape.*—The shape given to sewers is not governed by a uniform practice. Generally the egg-shape is adopted for all sewers of the combined system, when they are large enough to be entered; when smaller, the circular shape is preferred.

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* Proceedings Eng. Club, Phila., volume I, page 207, &c.

† Bürkli-Ziegler. Abflussmengen Städtischer Abzugscanäle. Zürich. 1881.

‡ Parenthesis and sub $_1$ indicate English measure.

§ See Appendix. No. 1. London. C. II. 1.

‖ See Appendix. No. 1. C. II. 1, under the various cities.

In Paris, owing to the method of cleaning by flushing trucks, a composite section is necessary. The sewage itself flows in a channel (cunette) which it fills from several inches to several feet, and the edges of which are provided with rails for the trucks. At one or both sides of it are foot-paths for the workmen, and the whole is covered by a semicircular arch. Water-pipes and telegraph wires are usually suspended in them, to be accessible at all times. Branch sewers in Paris are oval.

A great difference is noticeable in the section given to egg-shaped sewers. Some, as in Paris, Vienna, and Hamburg, have a comparatively flat invert, others more pointed ones, as in England, in Frankfort, and Berlin. The latter appeared far more preferable and were found to need less cleaning and flushing than those with flat inverts.

It is customary in some cities, as in Liverpool, to make all sewers in public highways large enough to be entered and passed through, confining pipe-sewers to private and so-called back drainage, where the sewage is collected in a pipe running along the back of a row of houses and discharged into a brick sewer on the main street. The advantage claimed is a more ready control of the works. In Frankfort, where many of the sewers were built by tunneling, on account of the narrow streets, it was also preferred to build brick sewers three feet high, where otherwise a pipe sewer would have sufficed.

*c. Gradients.*—Generally the grades are adapted immediately to the surface of the ground and, as a rule, they are made as great as practicable, not only to reduce the size and cost, but to remove the sewage as quickly as possible.

In Berlin it was held that the velocity should not be so great as to reduce the section of the stream below what was necessary to give a constant flow, and therefore to decrease the tendency to deposit. In England it is recommended not to cause the velocity to be greater than six feet per second, in order to prevent a wearing away of the invert and to leave ponderous solids high and dry.*

The minimum grades are made to depend on the size and object of the sewer. House-connection pipes were seldom given a grade less than 1:50; valley-line sewers rarely had grades less than 1:1,000, and intercepting sewers were given grades down to 1 in 4,183, as in Paris. In Hamburg, and Westham near London, some were even built on a perfect level, so that the water could be made to discharge in either direction as desired with reference to flood-heights.

For sewers of the combined system it is necessary to consider two conditions: First. To properly convey and discharge the ordinary flow of sewage, the grades of the sewer should be sufficient to prevent deposit of silt, but not so great as to injure the sewer. Secondly. To properly convey and discharge storm-water, it is necessary to consider the hydraulic gradient instead of the grade of the bottom of the sewer, except where they naturally are parallel. For the conveyance of storm-water, therefore, the highest points to which the water can be allowed to rise, without flooding or damaging property, should be ascertained. The line thus given is a guide for the grade of the storm-water, which ought not to rise above it at any place. This point has occasionally been overlooked. The floods in London, April, 1878, were said to have been partially due to this cause.

The outfall of a sewer into tidal rivers makes this consideration specially important. The ordinary sewage should be discharged freely at low water. The bottom of the sewer must therefore be adjusted with reference to the latter point, in order to avoid permanent backwater and deposit. The storm-water should be discharged freely at times of high water, and its velocity must therefore be calculated from the hydraulic gradient at high water in order to maintain its full capacity at all times. (See Fig. 9, Pl. VIII.)

As the velocity, when the grades are equal, increases with the section and decreases with the length of the wetted perimeter, or, in other words, increases with the hydraulic depth of water, it follows that smaller sewers, to give the same velocity as larger ones, must be given more gradient. Towards the periphery of the areas, the grades are therefore steeper, and the profile of one sewer, increasing gradually in size towards the lower end, will, if properly designed, show in general a vertical curve, being concave towards the top.

Finally, the fact that a well-built sewer with good alignment may occasionally give a greater velocity with the same grade than a river, has been made good use of in Frankfort. By discharging into the river some distance below the town, it was possible, by giving the sewer less grade than that of the river, to drain houses in the lowest sections of the city, which otherwise would be constantly affected by the flood waters.

*d. Construction.*—One of the essential reasons why the European sewerage works, wherever a pretense is made of having a system, are better than most of our own, can be found in the greater care which is generally given to their construction. The materials are more carefully selected, and, as a rule, the works are more substantial and have a better finish given to them.

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*Rawlinson: Suggestions to Local Government Board. Also Pilbrow: Separate System in Tottenham, page 10.

In nearly all cities it has been a main endeavor to make sewers water-tight, not only to prevent sewage from soaking into the surrounding soil, but to prevent subsoil-water from draining into the sewers. In Berlin and Oxford this effort appeared to have been most successful. In both of these cities all sewage must be pumped to a considerable elevation for purification on farms, and in both the sewers were to a great measure below the level of a freely running subsoil-water, therefore making water-tight sewers a matter of great economy. In Frankfort the subsoil-water was also abundant, but as the sewage flows away by gravity the sewers were in places allowed to act as drains. This feature would never be objectionable if the sewage could always discharge into the river. At present the latter is causing trouble; restrictions are placed by the government upon the further admission of sewage, and purification, on account of the subsoil-water admitted, will become more expensive than otherwise. For draining away the latter as it accumulates in the sewer trenches drain-pipes have sometimes been laid below the sewer, as in Oxford and Berlin; and above or to each side of the sewer, as in Vienna and Breslau.

An important feature, as already indicated, is the degree of roughness of the perimeter of a sewer. It affects the amount of adhesion of floating particles, forming the "siel haut," and also the velocity of the water. In both cases it is of advantage to give the interior as smooth a surface as practicable.

Pipes, except near the dwellings, where grease adheres to the sides, show but a slight coating of adhering matter as compared with sewers of brick or stone. Concrete, when smoothly plastered, likewise shows but a slight coating, if any. The odor from concrete sewers, other things being equal, is said to be less than from brick sewers, and it appeared so from my inspection.

In Vienna one of the reservoirs for storing the drinking-water was partly plastered with a smooth lining of cement and partly was faced with sandstone. The clean condition of the former compared with the slimy, greenish surface of the latter, although built the same time, seems to confirm this opinion.

The materials which seemed to be best adapted for sewers and which were generally preferred, where the cost was not too great, are vitrified pipes for sizes less than 18 inches diameter, and concrete for larger sizes. The next best material is brick-work carefully laid and jointed. Iron was preferred for the main house-pipes quite generally, and was compulsory for the entire system when built according to the Liernur plan. Rubble or other stone is not used now, except in Paris, where it is, however, plastered to a smooth surface with strong cement.

Wherever a difference was made, the *hardest* materials were built into the invert to prevent scouring, as the "blue bricks," in England.

### 3. *Junctions.*

Under this head it will be in place to examine into a few other points, which have given more or less trouble in retarding the flow of sewage. This imperfection has been caused by an improper direction of the joining streams, by backwater, and by eddies in depositing silt or in checking the discharge, so that the full capacity of the sewer is not available.

The proper direction of the joining streams has a material influence on the velocity of the combined stream. The junction-angle should therefore be arranged so that the direction of flow of the two streams before joining is as nearly as practicable the same. Neither will then lose much velocity in endeavoring to overcome the change of direction. The less the sizes of the respective streams differ from each other the more essential is this consideration.

The junctions of larger sewers are best made with as long a radius as possible; and this feature we find pretty well considered in England and in the German cities of Hamburg and Frankfort. In Berlin some of the main junctions of large sewers are at right angles, or nearly so. Considerable deposit was noticed there, and probably other serious consequences have not been found only for the reason that the velocity in the sewers before joining is not great.

When small sewers or house-pipes unite with large sewers it is almost the universal practice to give the former an angle of 30° to 45°. It has been asserted that such junctions at times of rain can even accelerate the flow of water in the sewer. Although this is theoretically true, the effect is slight at best, and no practical confirmation of any value has been observed.

To reduce the size of a sewer by anticipating this increase of velocity is not advisable, and it is considered a very satisfactory condition if junctions do not cause an actual retardation of the flow.

When two or more pipe-sewers join, the entire curves, as previously mentioned, are made in the man-holes, so that the entire length of the sewers can be sighted. The smallness of the stream in pipe-sewers does not make this short turn objectionable. The loss of head in turning is compensated by an increased fall in the man-hole.

An important feature of junctions is, further, the relative height of the joining streams. Unless this point is considered, backwater and deposits may occur in one of the branches. Theoretically, then, the joining sewers should be so shaped as to constantly deliver the sewage of each at the same level. To comply with this demand for all conditions is impossible. It will suffice, however, to consider the ordinary flow which exists during 90 per cent. of the time. The surface of the latter in the branches should, therefore, be either the same for all, or increase in height as the bulk of the sewage becomes less. In other words, the smaller sewers should join larger ones so that their ordinary flows meet at the same level, or so that the smaller sewer discharges at a higher level. The junction of three sewers in Frankfort (Plate VII) illustrates this point.

When two streams discharge into a man-hole opposite each other, at points above its bottom, they should be placed at different heights, or else receive a slight lateral turn so that the full discharges do not directly meet each other.

The third consideration of importance in junctions is the prevention of eddies, which also tend to cause deposits, besides retarding the flow.

Eddies are produced by sudden changes in the cross-section of a certain body of flowing water. Such sudden changes must therefore be avoided and the cross-sections of two joining streams be merged into each other gradually. The so-called "tongues" are the means by which this is effected. Instead of letting several sewers discharge into a flat-bottomed chamber, the inverts should strictly be extended until the respective surfaces meet. This condition is practically approached as near as possible, and the "tongues" terminating in a point are thus formed. (See plate VII, junction in Frankfort.) Eddies, and therefore deposits, are entirely avoided in this way, which an inspection fully confirmed. While I noticed no deposits in the junctions provided with tongues in England, Frankfort, and Hamburg, considerable silt was noticed in some junctions in Berlin and Paris which were formed by rectangular and flat-bottomed chambers.

Even in a man-hole, where several sewers join, the tongues are just as effectual in preventing deposit. The inverts are carried around by curves until the surfaces intersect, the entire bottom being usually formed of concrete, and smoothly finished. These man-hole junctions are now generally preferred to the former custom of letting the pipes terminate flush with the wall of the man-hole, thus forming a basin for deposit, as customary in Danzig and Berlin and in the older works in England.

### 4. *Appendages.*

In order to secure a proper reception of street-water and a ready means of inspecting sewers, certain appendages to them are necessary. Only such points shall here be considered as are essential, and which, when insufficient attention has been given to them, have caused imperfect action.

*a. Street inlets, basins, or gullies.*—They consist of—1, an opening or inlet to receive the street-wash; 2, a basin to retain silt, if this is deemed necessary; 3, a trap to prevent sewer air from escaping, if this is likewise deemed neccessary; and, 4, a pipe connecting the structure with the sewer.

The *opening* is either horizontal, placed in the gutter and covered with a grating, or it is vertical and flush with the curbstone, or both plans are combined. A grating in the gutter can only answer when the streets are kept free from matter which could clog the openings, such as leaves, manure, &c. They are extensively used in Europe. (See Table I.)

TABLE I.—*Street inlets and gullies.*

| City. | Location and distance apart. | Common position and size of opening. | Depth of basin below surface. | Trap and seal. | Diameter of discharge-pipe. | Remarks. |
|---|---|---|---|---|---|---|
| London | Within block, 150 to 300 feet | Grating in gutter, 16 by 18 inches. | About 4 feet | 6 to 12 inches | 6 to 9 inches | Some have neither trap nor basin. |
| Paris | Within block, varies with grade | Side opening in curb, 4 by 40 inches. | No basin | None | At least 4 feet high. | |
| Berlin | Within block | Grating in gutter, 16 by 20 inches. | 7 feet 4 inches | Screen in place of trap. | 6 to 9 inches | |
| Vienna | Within block | Grating in gutter, 12¼ inches to 18¾ inches square; side opening in curb 4 by 12 inches. | 4 to 6 feet | Some are trapped. | 3 to 4 feet high. | |
| Liverpool | Above intersections, 200 to 300 feet | Grating in gutter, 12 by 14 inches. | 4 feet 6 inches | 14 inches | 9 inches. | |
| Hamburg | 140 feet | Grating in gutter, 15 by 17 inches. | 4 feet | None | 9 to 12 inches. | Basins are only used on macadamized streets. |
| Frankfort | 120 to 150 feet | Grating in gutter, 13 by 18 inches. | 7 feet 8 inches | 6 inches | 6 inches | Iron bucket is placed in basin to catch the silt. |
| Danzig | At intersections, 200 feet | Grating in gutter, 10 by 14 inches. | 5 feet 9 inches | 6 inches | 6 inches | |
| Brighton | 150 to 300 feet | Grating in gutter, 16 by 27 inches. | 2 feet 9 inches to 3 feet 6 inches for iron basins; 5 feet for concrete. | 6 inches | 9 inches | The large concrete basins are not trapped. |
| Oxford | (?) | Grating in gutter, 14 by 18 inches. | 3 feet 6 inches | (?) | (?) | Have a basin and a trap. |

A vertical opening on the line of the curb is therefore more expedient, as it can be obstructed by the ordinary street-wash. But it is only safe when the dischar pipes as well as the sewers are large and the introduction of bulky matter wh may find its way into them is not objected to.

A combination of the two methods may be considered a transitional state, b practically the same as the second and more expensive.

Where sewers are large and the grades are not too light or when there are g flushing facilities, side openings in the curbs are preferable. For pipe-sewers, light grades, gratings in the gutters are necessary.

The size of the openings when grates are used varies from 10 by 14 inches in Dan to 16 by 27 inches in Brighton. (See Table I.) The side openings are shallow, fr 4 to 5 inches high, and 12 inches to 40 inches long. When located at the corners streets, as usual in America, the inlets require a turning of the stream, and the fore cause some damming up, thus necessitating a greater section than when in are above the corners, as is common in Europe.

Another essential part of the gully is the *basin* for the retention of silt. Obj tions have been raised against it on account of the foul matter which may accum late therein. But when every house is connected with a sewer and the streets well paved and well cleaned, the water remaining in the basins does not become v offensive, and I nowhere found them so. When, however, much kitchen-waste r into them, or when the streets are kept dirty, a very frequent cleaning is necess to avoid offensiveness. Basins, furthermore, do not prevent the washing of fine into sewers during rain-storms, where it deposits as soon as the velocity diminish

Wherever it is at all possible to do without basins they should be dispensed wi In Hamburg and Paris the flushing facilities are such that they could be omitted all of the paved and well-cleaned streets.

In Frankfort the removal of silt is facilitated by placing buckets perforated n the top in the basins to retain the heavier solids, and permit of being easily tak out; in other cities scoops are used.

The depth of the basins varies with the climate. It will be noticed (See Table that in England they are comparatively shallow, while in Germany they are alm twice as deep on account of the severity of the frost.

Regarding the *trap*, we find it entirely omitted in Paris, Hamburg, and occasiona in London. In Leeds it was removed with good effects. In Berlin the original t now acts simply as a screen, being perforated at the top. Wherever the sewers properly built and well maintained the absence of a trap would seem to be rather benefit to the system than otherwise in permitting a better circulation of air. On where inlets are placed in narrow streets and near windows, has it been found nec sary in all cases to prevent the occasional escape of foul air. As a rule, the cleani facilities are such that a constantly perfect condition cannot be guaranteed, and t omission of traps must be treated with a great deal of caution. It could hardly recommended for American cities. In the table it is noticed that the depth of wat seal in the mentioned cities varies from six to fourteen inches, which fully guar against evaporation.

The diameter of the *discharge-pipe* into the sewer varies from six to nine inches those cities where the inlet is a grating in the gutter. The amount of water ev delivered to a sewer from them could be carried by a three or four inch pipe, but is preferable never to use less than six inches. Where side openings are placed the curb which permit bulky matter to enter, a larger diameter, at least twelv inches is customary. In Paris and Vienna the connections are large enough to allow men to go into them from the sewer.

The ordinary location of sewer-inlets in Europe is not at the street corners, as America, but slightly above them or near the middle of the block. They are als placed closer together than here, which explains their smaller capacity. This greater frequency appears to have no special advantage, but the avoidance of inlets street intersections has several. The deep gutters at the sidewalk-crossings are obv ated, which in winter are often very objectionable. It is further possible on suitab pavements and grades to allow the rain-water to run over intersections to anoth block. The advantage of this is a saving of inlets and the keeping of rain-water long as possible on the surface, which not only assists the cleaning of the pavement, but diminishes the size of the sewer below. The practicability of thus permitting rain-water to run across street intersections depends on having a smooth pavement such as Belgian block, wood, or asphalt, with a slight and suitable camber to avo pockets, conditions which are common in London, Liverpool, and many continental towns. It also requires the waste-water from every house to be led into the sewer, and that nothing but rain-water be allowed on the surface of the pavements. these conditions cannot be had, inlets are necessary at every lower junction of tw descending gutters.

A word may still be added with reference to the gutters themselves. They vary from ditches (two feet deep in the older parts of Berlin) to the simple depression caus slope of a cambered street and the curbstone, which is generally only three inches deep. The objectionable features of a rough and deep gutter are that ns rather than removes street dirt; that it is unsightly and sometimes even ous. Its best form in a sewered street is the natural channel formed by the of a smooth pavement with the curb. That the gutter should be as smooth ible, is necessary in order to allow a comparatively small amount of surface or ater to run off readily, and therefore cleanse it.

*an-holes.*—Accordingly as sewers are entered from the street or the sidewalks, ferent structures are used. When the traffic is sufficiently great so that an tion in the street, caused by opening a man-hole for inspection or cleaning, is ng, a passage-way is built from the sewer to the sidewalk, with an entrance latter. These are called side-entrances, and are used in the central parts of a, in Paris entirely, and in Hamburg and Frankfort in the most frequented . The only objection to them is their expense.

holes, when placed directly over the sewer, are by far the more common of the ntrivances. The section is generally round, varying from 2 feet 6 inches to diameter. In Vienna it is 2 feet square; in Liverpool rectangular, 2 feet by 1 foot 6 inches, and in Brighton 2 feet 6 inches by 3 feet. The circular form the best and is most economical. For pipe-sewers an elliptical section is pre- which gives room at the bottom to work in. In Liverpool a chamber is com- built for this purpose.

a large sewer the man-hole is built on its side-walls, the invert continuing its without interruption. For pipe-sewers in Danzig and Berlin, the man-holes een built with a square or rectangular bottom, letting the pipes enter above it, ming what has been called the "pot-and-pipe system." The objection to basins rmed is that they retain decomposing matter. The better plan, which is now d in England in preference, is to carry the pipe-sewer in semicircular section h the man-hole, and thereby offer no chance for deposit. As man-holes are ively used for ventilation, they are provided with the following arrangements t purpose:

me cities, notably Vienna and Hamburg, they are covered with an open grat- rough which the air can freely escape and the street dirt drop into the sewer.

ra, the man-holes are covered by gratings, partially open and partially closed locks of wood, intended to deaden the sound made by vehicles passing over In Berlin the holes are near the periphery, the blocks in the center. A few below the cover, a sheet-iron plate rests on a few projections. This plate, holes in the center, under the blocks, permits the circulation of air and at the me prevents street dirt from dropping into the sewer. In other cities, espec- a England, the holes are in the center, while the blocks are near the periphery. ket, box, or pan is then suspended under the center to catch the dirt, while tion is obtained at the periphery. Of these two plans, the latter seems to be y preferable, because the dirt can be more readily lifted out, and because the g has less metal exposed to the passing wheels. The common plan in England, e which is more expensive without offering additional advantages, is to close n-hole with a tight cover and to build a small catch-basin, communicating , to one side, which then receives an open grating about 9 by 18 inches in size, in being about two feet deep.

al point to be considered is the distance between man-holes.

aris it is fixed at one hundred and sixty-four feet, a deviation being made only a crossing or other obstruction compels it. In Vienna the distance is about two d feet; in Hamburg three hundred and fifty to four hundred and fifty feet; in fort five hundred and forty to six hundred feet for large and two hundred and three hundred feet for small sewers.

re pipes are used a man-hole is placed at every change of direction, usually at t intersection, and, on long straight lines, two hundred to three hundred feet The rule that the smaller the sewer the nearer should the man-holes be placed, ally observed. Where sewers are well built and well flushed, man-holes need as close as when the sewers require much clearing by hand labor.

*erflows and outfalls.*—Two more subjects require some inquiry, where imperfec- an have serious results.

*flows.*—Storm-water overflows are not practicable for sewers which themselves the nearest natural outfall. They are therefore confined to intercepting sewers, eir advantage consists in causing a reduction of size in the latter below an w.

designs are in use. One permits the ordinary sewage to drop through an open- the invert of a valley-line sewer into an intercepting sewer which crosses un- th it. The storm-water, which attains a greater velocity, leaps over the open- d continues its course to the river. Unless the size of this opening is carefully ed and allows of graduation, its action has been found unsatisfactory either in ing too much water into the intercepting or too much sewage into the overflow sewer. A better contrivance, and one more commonly used, is an opening in the of an intercepting sewer through which the water, after reaching a certain heig can flow off into some other channel. The proper height at which this is to beg must be determined from the degree of pollution permissible for the water deliver by the overflow sewer. The proper shape will be a long and shallow vertical rect gle, permitting a sheet of water to run over and to give the desired bulk. When intercepting sewer, which is to be relieved of the storm-water, is straight, the ov flow sewer should start with as easy a curve as possible, to prevent a check upon velocity, which, during heavy rains, might have serious results. A better plan is curve the intercepting sewer so that the overflow forms a straight continuation of while the ordinary flow makes a curve, because the storm-water would suffer less tention, having a greater velocity. The position and frequency of such overflo will depend on the pollution allowable, on the topography, and on the existing sewe which may be used for this purpose.

*Outfalls.*—The location of the outfall of a system of sewers will depend, not on on the topography and on the indications regarding the growth of the town, but al on the manner in which the sewage is to be disposed of. When purification is nec sary, the outfall must be at the locality where this is to be carried out. Common such places are below the town and near the water-course into which the efflue sewage can be discharged. In some cases, where no land is available below the tow the sewage must be carried to other points. In Berlin it is pumped to farms situat several miles from the river, the effluent discharging partially above the city. I Leamington and some other English towns the sewage farms are also not below b at one side, on some tributary streams. When purification is not required, and t sewage is discharged into a river or the sea, the location must in both cases be belo the town, to prevent pollution of the shores in front of it. Along the sea-coast th prevailing currents determine which direction is below. In rivers or estuaries, whe the tidal range is great, it is necessary to carry the outfalls so far down that the returning tides cannot bring back the sewage to the town. It will be necessary, besides, to store it either in reservoirs or tank-sewers during incoming tides, and to discharge it only at times which will prevent its return. If the outfalls are distant, the sewage can safely be discharged before high-water, as in London, and continue fo three or four hours after it. The main features regarding the location of the outfall are herewith indicated. It remains to examine into its position.

When pumping is necessary, it is a matter of economy to design the outfall so that the elevation to which the sewage is raised can be varied with the level of the body of water into which it is discharged. For tidal rivers, only such portion of the sewage may be pumped to the elevation of high tide as must be discharged at this elevation, as, for instance, at Crossness, London.

When sewage discharges by gravity, the position of the outfall is governed by the tides as well as by the elevation of the lowest part of the country which is to be drained. In all cases a sewer should be placed at an elevation which will permit of a free discharge of the ordinary flow of sewage at low-water. (See Plate VIII, Fig. 9.) Another governing point is, that the hydraulic gradient of the storm-water flow, determined at the highest spring tides, should be the gradient by which the size is determined. If this is done it matters not how far the sewer is placed below high tide, as it will never be tide-locked.

In fact it will sometimes be advisable to sink the outfall entirely below water, carrying it in a submerged conduit on the bottom of the river or bay to a point in the current, to have a more rapid dispersion of the sewage and to prevent it from accumulating in the docks and along the shores as in Hamburg, Brighton, &c.

When the hydraulic gradient cannot be raised to high-water at the outfall without causing the flooding of cellars, or even entire districts in the city, it will be necessary to close the outlet by a penstock or tidal flap, to prevent the tide-water from entering the sewer, which then acts as a storage tank until the tide recedes. This treatment is common in London, Hamburg, Danzig, and other places. In the case of a heavy rain-storm during the time when the sewers are locked against high tides serious results are apt to follow if provision is not made for this contingency.

In Hamburg the canals running through the city are also closed against the high tides in the river, and in thus forming a basin the storm-water overflows discharg into them at such times and relieve the sewers. When a similar expedient is not possible, the only guard against this trouble is the interception of rain-water and dis charge at higher elevations, or its removal on the surface by the introduction of th separate system.

### 5. *Ventilation.*

The question of ventilating sewers is one on which there are yet very decided an opposing views.

Many different methods have been proposed and tried, and none of them hav satisfied all requirements. A comparison, however, will show, I think, in what on we may find an ultimate solution.

ilation may be had in two ways: by means of natural forces at work in a sewer rtificial force. The former can, in the main, be stated to be as follows:

*he difference of temperature of the sewer and the atmosphere.*—While the latter varies y, the former remains almost stationary, thereby tending at one time to cause to escape from the sewer, at another to be drawn into it; or sometimes to along the sewer toward the higher parts of the system, and at other times to downward.

*hange in the quantity of sewage.*—Not only the varying amounts of water used in rellings, &c., constantly produce a change in the bulk of sewage, and, theref the air contained in the sewer, but during a rain-fall these changes become narked.

*rictional force of the flowing sewage.*—A current of water, as any other body in n, carries a certain quantity of air with it by friction. And this is true not only rtical but also for slightly-inclined pipes, and the amount of air drawn along is dent on the exposed area and velocity of the sewage and not on the size of the , except when it is running full or nearly so.

*Vind blowing over street-openings and into outfalls.*—Whenever a strong current of sses over a shaft-opening in the street it will affect the circulation in the shaft, by causing a downcast or an upcast, as the direction of the wind may be. A outlet exposed to the wind will cause a similar effect.

interaction of these forces produces a natural circulation of air in the sewers case. And it must be provided for if traps connected with the system are to ain their object.

artificial circulation of air is attained either by the plenum or vacuum sys- i. e., by the creation of a draught in forcing air into the sewer or in drawing it

will be evident that near the motive power the pressure is greatest, and that it iminish as the distance increases. Therefore a very unequal pressure is caused ghout the sewer. And unless it is air-tight and the traps sufficiently guarded hstand both the greatest and the least pressure, the effect of the artificial ht will decrease very rapidly.

ious appliances have been used for obtaining this artificial ventilation. The successful example that came within my notice was in Brighton (Appendix No. II, 4), where a large stack, 200 feet high and 6 feet in diameter, has been built ntilate 2 miles of an intercepting sewer. A fire is kept burning constantly, and raught is just noticeable at 2 miles from the stack, when all openings on this h are carefully kept closed. There are no house connections on this line. Al- h there may be instances, like this one, where artificial ventilation is to be red, it will be evident that it cannot be recommended for entire sewerage sys- but is only useful where there is no danger of destroying traps, when the al circulation of air in the sewers can be counteracted with sufficient force, and no more economical mode of ventilation is advisable.

natural method of ventilation is otherwise to be preferred, and it remains to me into it more closely.

forces operating in a sewer, it has been said, compel the air sometimes to flow t, and at other times to flow out, and to rise to the higher portions of a sewer fall to the lower ones. By facilitating this free motion of the air, a natural lmost constant circulation is obtained.

means employed to facilitate this action are shafts communicating with the air. High shafts have been built at the upper ends of sewers, as, for instance, ankfort. But, although the impure air is led off effectually, the expense of towers is hardly warranted, because cheaper means will accomplish the same t. Gas-posts have sometimes been used as ventilators. In Glasgow, for instance, it was expected that the heat would create a current, the latter idea has been up as there are frequent downcasts, and the posts are now used simply to enable ewer air to escape when necessary above the pavement in a way not to be an- g to pedestrians.

rain-water pipes of houses, when connected with sewers, have also been pro- as ventilators for the latter. Yet this is objectionable, not only because they a rule insecurely jointed and often open out near garret windows, but because do not act at the time when their action is most needed, namely, during a rain. olumn of falling water tends to carry air down with it, instead of letting it e, when the sewer is filling up with water and endeavoring to expel the air. rain-water pipes are the only means of ventilating sewers, their action is even ly cut off when the sewers fill up above the point where the house-drains enter.

soil-pipes of houses carried above the roof are now much used for sewer venti- n, and have fewer objectionable features than the rain-water pipes. When they side of the houses and are not well jointed, the danger of the escape of sewer air into the dwellings is apparent. But it must be said that as a rule the house-pipes will always be in a worse condition than well-kept sewers, and, therefore, if the pipes are sufficiently tight to prevent any escape of gases originating in the house-pipe itself, they will also prevent an escape of gases from the sewers.

A valid objection to soil-pipe ventilation, if it is to be the only method employed, is again the fact that if the water in the sewers rises above the house connection, all ventilation through houses is stopped. This might be obviated by leading house-water into the sewers at the soffit. But this would not only cause the sewer to be impassable, but require that it should be built to a greater depth than if the house connections enter at or near the springing line.

The advantages on the other hand are, that the circulation in the house-pipe itself is facilitated by the pulsation of the sewer air, and that the lower opening in the house drainage near the sidewalk or yard is avoided, where often disagreeable exhalations are noticed. Still another advantage lies in the circumstance, that when the ventilation through street-openings fails, as in winter when heavy snow or ice covers them, the action of the soil-pipes as ventilators is not impaired.

In England, ventilating sewers through soil-pipes is objected to, because an escape of sewer air into the house is feared. In Germany, it is advocated in Hamburg, Frankfort, Berlin, Danzig, and other towns. The great amount of snow and ice during the winter in German cities, obstructs the ventilation through street openings, and other methods are compulsory. As the winters in England are very light, the necessity for other ventilation than that obtained through street openings does not appear. This circumstance may partially explain the different customs and opinions.

Lastly, the most common and most effectual method of sewer ventilation is that of leading shafts from the sewers up to the surface of the street and covering them with an open grating.

This plan is also the cheapest, because it requires but a slight additional expense for the structures, such as the man and lamp holes, which themselves are necessary for other purposes.

The contrivances to permit free exchange of air and to catch the street dirt dropping through the openings have already been alluded to. It is now necessary to inquire into the effects of ventilating into the street.

If the sewer air is uniformly diluted when it escapes at the surface, its quantity at any point decreases very rapidly, *i. e.*, as the cube of the distance from the opening. As a matter of observation, I found only in rare cases any noticeable odor at the distance of a few feet from the ventilators, and then it was only the case when the sewers were declared to be in an imperfect or unclean condition. When they were moderately clean the exhalations were in no way objectionable.

As it is impossible in all cases to guard against the escape of some foul air, various devices have been proposed to purify it. Among all of them the charcoal method is the cheapest, best, and most used. The appliances consist of a basket of spiral or other form, in which the charcoal is placed so that the sewer air, in escaping, passes over it. The great absorbing power of charcoal is in this way made use of to absorb the gases. This basket is suspended near the top of man-holes, or of special shafts, or it is placed between the man-holes, which then receives a closed cover and a side catch basin with a grate cover, in such a manner that no air can escape without coming into contact with the charcoal. The action is good if the latter is prevented from absorbing too much moisture and is not in use over six months. The expense of charcoal and its continual replacing precludes a general adoption of this method, and it is now used only in places where the escaping air is very obnoxious.

In order to ventilate sewers into the street without causing a nuisance, it therefore becomes necessary to build them in a manner which will secure a good circulation of air at all times, and also to keep them clean, which latter is necessary, from an independent point of view, to prevent as much as possible decomposition, propagation of germs, and expulsion or escape of air in undesirable ways, and finally, in order to enable them to be entered without danger. Whenever it may not be possible to secure this condition permanently, some other more costly or less efficient method of attaining ventilation must be employed, which local circumstances will determine. It may be advisable to insert charcoal ventilators at certain points, or, in short sewers, to use the outfall in connection with soil-pipes, and to omit ventilating man-holes entirely.

The *conclusions* which present themselves may now be stated as follows: The most economical and effective method of ventilation is by short shafts in the streets, placed at frequent intervals. The next best method is a free communication with the outer air through the soil-pipes of houses, under the proviso that they are properly constructed.

As the former method often becomes inoperative in the winter, and the latter requires the overcoming of considerable friction, owing to the length and comparatively small size of the pipes, which greatly retards the circulation, neither solely appears to answer all conditions. Both methods in conjunction, however, satisfy in general the requirements. Ordinarily the steeet-opening would effect the exchange of air, and the soil-pipes would draw the air necessary for their own ventilation from the sewers. When the former do not act a circulation can then be secured through the latter. If it is required to guard against all contingencies, it remains yet to provide for the case, when both the man-hole covers are closed by snow or ice and the sewers are filled from a rain or sudden thaw, so that the house-drains are also inoperative. This condition can be satisfied by leading a special safety ventilating pipe from the soffit of the highest point of the sewer and from man-holes, as may be desirable, into special stacks, chimneys, gas-posts, or house soil-pipes, according to necessity or convenience.

It appears, therefore, finally, that the natural method of ventilation provides for all cases; it can secure a sufficient circulation at all times; it is more economical, and therefore, on the whole, preferable to the artificial method.

## IV. MAINTENANCE OF SEWERAGE WORKS.

A striking contrast is observable between the average ordinary condition of the sewers in Europe and in America, and it is in this want of proper maintenance perhaps more than in any other point that our sewerage works have often failed to answer their intended purpose.

If sewage were a uniform substance like water, gas, or air, its conveyance through channels could be as readily accomplished as the water and gas supply of a city. But the sewers contain fluids, solids, and gases of the greatest variety in bulk and weight, and sometimes in proportions which cause injurious conditions or imperil the proper action of the sewers.

Entire self-action, therefore, cannot be relied upon. Occasional inspection is unavoidable in order to prevent serious obstructions, and artificial assistance in removing deposits becomes necessary from time to time.

Several methods of cleansing sewers are in vogue.

### 1. *Free flushing by means of sewage or water from the town supply.*

This is the most common and cheapest way of removing deposits. The appliances for it vary with the size of the sewers, and with the customs in different cities.

At the head of a small pipe-sewer it is difficult to collect enough sewage in a short time to flush the same; therefore city water is generally used at such places. In Liverpool the end of the pipe is bent up to the street surface, and there is fed by a hose attached to a fire-plug, or large iron flush-tanks, mounted on wheels and filled with water, are suddenly discharged into the sewer. In most cities, both in England and Germany, a flushing shaft is placed at the highest point, and is filled from the city water-pipes. On drawing a valve, or stopper, the entire contents are suddenly discharged through the pipe. Man-holes on the line of the sewer are also often used as flushing shafts, as in Danzig, Berlin, London, and Oxford.

Field's self-acting flush-tanks have occasionally been inserted at the ends of sewers in England; one at Aylesbury, 12 inches diameter, has been in use for several years. They require occasional inspection, and are only satisfactory when supplied with clean water, not with sewage.

· When the sewers are larger than 12 inches or 15 inches, it becomes necessary to use a greater bulk of water than can be collected in a man-hole, shaft, or tank. The sewage is then dammed until a sufficient amount accumulates, which is suddenly released. Small sewers of 12-inch to 18-inch pipe are dammed by flushing slides, which are placed in front of a pipe in a man-hole and drawn from above. In Oxford, for instance, the sewage is allowed to rise to a head of from 18 inches to 3 feet before the slide is drawn.

Brick sewers have gates and pen-stocks for the same purpose. The former are better than the latter, because they are swung from the side and open suddenly, whereas the latter, worked from above, are raised by means of a screw. Wherever a large body of water is to be mastered, pen-stocks are preferred, and the mechanism is usually arranged so that one man can operate it.

Where the grades are light and the damming of sewage in larger sewers would drive it back into smaller ones, flushing has sometimes not been favored. In Berlin, for instance, it is only used for the smaller sewers, while the larger ones are cleaned by hand.

The alignment advocated by Mr. Lindley and executed in Hamburg and Frankfort is arranged as already mentioned, with reference to the avoiding of dead-ends, and the facility of flushing small sewers from larger ones. The sloping ground is crossed by intercepting sewers, and the branches of the districts below each one of them are connected with them, so that the water from the intercepting sewer can at any time be turned through one or more branch sewers, thus giving them a powerful flush. In Dantzig, a similar object is accomplished by leading a pipe sup with clean water along the periphery of several large areas and connecting the h est ends of the branches with it. At any time the entire contents of this pip be turned into any of the smaller sewers.

River water has also been used in a similar way, where the sewers were belo level at the upper end and above it at the lower, as in parts of Danzig. Sea w has likewise been of service in this direction. At spring tides, the sea water i mitted at the upper end of the long intercepting sewer in Brighton for four or days in succession. It is stored for two or three hours, and then allowed to s down to the lower end, which it reaches at the time of low tide.

As the effect of a flush is gradually lost by a decrease of velocity and an equa tion of the flow, it is necessary to place the flushing gates, &c., at frequent inter The distance apart also depends on the gradients, as it is generally required t the full benefit of a flush before the water is again penned back. A local consi tion, therefore, must decide what distance is best. In Europe it varies greatly, r ing from 300 to 5,000 feet.

The method pursued in flushing is, generally, to begin at the highest point work downwards. In this way the silt is gradually flushed down and out. In I burg, the lower parts are cleaned first, which has the advantage of preventing a accumulation of silt toward the end of the flushing.

The frequency with which sewers are flushed likewise varies. In Berlin the p is two weeks, in Danzig and Frankfort three weeks. In Hamburg the sewers b the Alster basin are flushed twice a week; the rest are flushed every two to t months. In England, sewers are flushed at intervals of one to three months. A time of flushing there is usually an inspection, and a monthly or quarterly reco sometimes kept of the condition of the sewers, as in Hamburg, Frankfort, Berlin Vienna.

### 2. *Flushing by means of a movable dam.*

Under this head I shall group the method of cleaning sewers which is the com one in Paris. According to it the sewage is dammed up by an artificial and mov obstruction, which nearly fills out the invert, leaving but a narrow space aroun perimeter. The available cross-section of the sewage is reduced thereby, so tha velocity is correspondingly increased. This increase loosens and scours up th which is slowly and automatically pushed along in front of the artificial dam, w is itself moved by the rising water in the rear. This dam consists in open se usually of vertical aprons or scrapers (French, vanne), which are suspended fro front either of boats floating on the dammed-up sewage, or trucks running on fastened to the edge of the inverts. In submerged sewers or syphons the same e is accomplished by a ball (French, boule) of slightly less diameter than the se which in this case must be circular in section.

In both cases the propulsion is automatic, as it is caused by the water itself, although the process is a slow one (about 2,500 feet can be gone over in a da effectually accomplishes its object.

In operating the scraper it is necessary to adjust its height with reference to amount of scour required. If there is a considerable amount of silt in the bott is possible to remove only a top layer, as it were, and to lift the dam accordingl second or even third flushing is then required to remove it all. Whenever amount of silt in front of the dam accumulates so that the motion of the latter i paired, the silt is dredged out and loaded into a boat or a tip-wagon, as the case be, in which it is removed to an outlet.

The syphon at the Pont de l'Alma, crossing under the river, and which is one m in diameter, is cleaned by passing the ball about once a week. A head of wat 1 foot 8 inches to 7 feet can be obtained, which has always been sufficient to rol ball through in a few minutes. In England this method of cleaning syphon also been tried, but in smaller pipes and with less success. It appears that a l mass of water causes the ball to act with more certainty than a small one.

It will be evident that the cleaning of sewers by movable dams must be mor pensive than by a free flush. Yet where grades are so light, as in the large collect Paris, the latter would have but little effect, and so the additional cost is just especially as it is much less than for cleaning by hand, the only alternative.

### 3. *Cleaning with hand tools.*

Where the foregoing methods are not available, or do not remove the obstruct a partial or an entire cleaning by hand becomes necessary. In Paris and Live small trucks gauged to run on the inverts are used to convey the silt, which is s eled into buckets placed upon them, to the man-holes, and there lifted out, or, to the larger sewers and there dumped into the fluishng trucks. The tools ıre scrapers, hoes, and shovels of suitable shape and size. The larger sewers in ı, which are not flushed, are cleaned with hoes, by which the silt is dragged to ;e catch-basin at the outlet. This cleaning is done every two weeks, but the -basin is cleaned daily of the silt carried down by the ordinary flow. In Oxford, m-stocks are so arranged that certain sections between them can be temporarily ed against the sewage from either end, which permits the removal by hand of s obstructions, and also a general examination of the condition of the sewer.

Brighton, where a good deal of sand washes into the sewers, large catch-basins laced on the line, especially just before discharging into the intercepting sewer. are cleaned every day or two.

Vienna, where flushing has not yet been introduced, the contents of the house ges, which are large enough to be entered, are scraped out once a month into public sewers. These are then cleaned at intervals varying with the grade. s having a fall of less than 5 feet per 1,000 are cleaned once a month; those g a grade between 5 and 10 feet per 1,000 every two months; and all over 10 feet ,000 are cleaned every three months. When deposits are reported to be greater 3 inches, a special cleaning at intermediate intervals is required.

points where flushing does not always remove silt effectually are the stretches which a heavy grade has changed to a light one, and therefore checked the ity. Also at the lower end of a flushing section, where the stream has lost its , deposits are likely to remain. At such places, after-cleaning by hand is some- resorted to.

hen pipe-sewers cannot be thoroughly cleaned by flushing, it is necessary to in- tools and to draw them entirely through. In England, circular brushes are used his purpose; they are drawn by means of a rope first floated through by a flush. erlin, cylindrical brushes, filling the pipes, and 1 foot to 18 inches long, are used larly. When this does not answer, one-half inch iron pipes, 6 feet long, are at- ed to each other with a disk at the end, and are pushed through the sewer. In ig, brushes and disks are also used in this way. In Berlin it is sometimes found dient to use both the cylindrical brushing and flushing at the same time, the former ning the silt, the latter assisting the motion and cleaning.

hen neither of the foregoing methods is available, jointed hooks are sometimes ted, which close when pushed into the pipe, but open by means of a spring when d back, acting then as a hoe.

word must also be said here about the cleaning of catch-pits under street in- or gullies. In Frankfort every gully has a bucket standing in it, into which the lrops. These are lifted out and emptied at intervals of from three days to three s, according to the character of the pavement and the weather—generally every weeks. In all other cities the basins were cleaned by scoops at intervals varying ove.

### 4. *Management of sewerage work.*

Appendix No. 1, under B, I have given outlines of the organizations in charge of age works and of the manner in which these are conducted. It will be seen that atters concerning their design, construction, and maintenance are generally r the supervision of one and the same department. In London, on account of the large territory, it has been found expedient to intrust the construction of branch s to the "district boards" of the respective sections, each one of which has an neer with a corps of assistants. But all plans must be approved by the metropolitan d of works, which is charged besides with the making of all designs, with the ling of all works connected with the intercepting system, and with main valley or "Schedule D" sewers, as they are called.

Paris the water supply and sewerage works are placed in charge of one depart- . The water-mains are placed in the arches of the large sewers, and in still other r points the two subjects stand in some relation to each other. Therefore, to itate the operations, they have remained under a single department.

Berlin, where sewerage works are at present being extended over the entire city, cial department was established for the design and construction of the new system. uties will expire on completion of the works. As soon as a section is finished it ned over to a permanent department which is charged with its maintenance and the extensions that may from time to time become necessary.

the remaining cities the design, construction, and maintenance are placed under ead.

execution of the work is differently treated in different places.

rule all new works are built under contract, Berlin being the only prominent where the department itself takes charge of the entire construction. The main- ce of the sewers, on the other hand, is quite generally conducted by depart- officers, and in rare cases is contracted for. Before the year 1871 the London sewers were cleaned and repaired under contract; but then it was decided to have them cleaned thereafter by men under the immediate direction of the board, repairing only to be done by contract as before.

In Paris all new works and repairs are under contract, but cleaning is done by department employés.

In Vienna new works, repairs, and cleaning are all contract work, the passages leading from the sewers into the houses, and into which the various house pipes discharge, even being included.

In the remaining cities, as a rule, the departments maintain the sewers with a permanent corps of men and contract only for new works.

As to the actual condition of the sewers as found by my inspection, I have to state that among the larger cities the cleanest works, as a whole, appeared to be those of Frankfort, Hamburg, and Paris. The sewers lately built in London, Liverpool, and other English towns were also in a very good condition as far as they were examined. In Berlin the flat gradients showed considerable deposit of soft mud and fine silt, readily yielding, however, to a strong flush, except in rare cases, when the accumulation of sand and grave obstructions necessitated other means.

In Germany the cleaning is generally done at night, especially when the man-holes are in the roadway. When entered from the sides, day cleaning is not considered objectionable. In Vienna, where the silt is lifted out of the sewers and carted to the Danube Canal, there to be loaded into scows and removed, the cleaning is also done at night. In Paris and England the sewers, as a rule, are cleaned during the day.

## V. COST OF SEWERAGE WORKS.

The costs of various items connected with sewerage works, as far as they were ascertainable, are given in Appendix No. 1, under E, for each city. The following table is compiled and extended for those cities only where the information was sufficiently complete. To be rightly understood the figures must be compared with some allowances on account of the different conditions of each town.

TABLE II.—c.

| City | Sewered area. | Population contributing to sewers. | Density per acre of sewered area | Length of sewer | | |
|---|---|---|---|---|---|---|
| | | | | Total. | Per inhabitant contributing to sewers. | Per acre of sewered area. |
| | *Acres.* | | | *Miles.* | *Feet.* | *Feet.* |
| London | 60, 000 | 4, 200, 000 | 70 | 2, 276 | 2. 86 | 200 |
| Paris | 18, 000 | 2, 000, 000 | 111 | 393 | 1. 04 | 115 |
| Berlin (Rad system. III.) | 964 | 110, 000 | 114 | 49. 3 | 2. 37 | 270 |
| Vienna | 15, 500 | 1, 000, 000 | 64 | 142 | . 75 | 49 |
| Liverpool | 6, 800 | 680, 000 | 100 | 668, or | 5. 18, or | 519, or |
| | | | | 350 excluding sewers in back passages. | 2. 47 excluding back drainage. | 247 excluding back drainage. |
| Hamburg | 7, 500 | 374, 000 | 50 | 131 | 1. 84 | 92 |
| Frankfort | 1, 300 | 95, 000 | 73 | 69. 6 | 3. 87 | 283 |
| | | | | | 2. 90 (estimated when all houses are connected). | |
| Danzig | 1, 200 | 80, 000 | 67 | 25. 8 | 1. 71 | 113 |

### TABLE II.—*b*.

| City. | Cost of— | | | | Pumping per head per annum proportioned to population for which sewage is pumped. | Remarks. |
|---|---|---|---|---|---|---|
| | Construction. | | Annual maintenance, excluding pumping. | | | |
| | Per foot including appurtenances. | Per inhabitant now contributing to sewers. | Per foot. | Per inhabitant contributing to sewers. | | |
| London | Main drainage, including pumping-stations $53 00<br>Valley-line sewers 12 30<br>General average 5 68 | $16 00 | $0. 060 | Main drainage $0. 03<br>Other sewers 0. 14<br>Total 0. 17 | 0. 08 | Sewage pumped, 18–36 feet. |
| Paris | Common sewers 9 50<br>House branches 3 00<br>Average (excluding house branches and including appurtenances) 9 62 | 10 00, excluding house branches | 0. 130 | 0. 135 | 0. 08 | System not quite completed. . Sewage pumped, 36 feet. |
| Berlin (Rad. System. III.) | Average (including pumping-station) 5 80<br>3′ 3″ × 2′ 6″ sewers 5 40<br>Pipe sewers 2 75 | 13 75 | 0. 043 | 0. 101 | 0. 158 | Sewage pumped, 72 feet. |
| Vienna | Average 6 10 | 4 60 | 0. 093, including considerable repairing. | 0. 070 | | System not quite completed. |
| Liverpool | 3′×2′ sewers 5 00<br>Average 3 70 | 19 00 | 0. 029 | 0. 147 | | Sewers in back passages are about 350 miles long. Average cost of remaining sewers, per foot, is $6 50. |
| Hamburg | Average 6 10<br>Mains 22 50<br>Branches 3 90 | 11 25 | 0. 036 | 0. 066 | 0. 10? | |
| Frankfort | Average 5 71 | 22 10<br>16 58, estimated when all houses are connected. | 0. 035 | 0. 137<br>0. 103 estimated when all houses are connected. | | Only about ¾ of population on the line of the sewers contribute to them. |
| Danzig | Average 3 65 | 6 25 | (*) | (*) | | |

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* Maintenance and

The *length of sewers* per inhabitant making use of them is given as it exists at present. Yet without some explanation it may mislead.

The figures for London, Berlin, Liverpool, Hamburg, and Dantzic apply to areas where the sewers are complete and where practically every house is connected. Among these the figure for Liverpool is very high, because it includes the sewers in back passages, which in other cities are partially represented by private house drains. Deducting these, the length reduces itself to one not essentially varying from the rest. The system of back drainage, although it increases the length of public sewers, greatly diminishes the length of house sewers. The length in Frankfort is also proportionately high, but this is due to the fact that all houses on the line of the sewers have not yet been connected. It may ultimately be reduced about one-quarter. In Paris and Vienna the systems are not yet complete. The length per inhabitant is, therefore, small. After making these allowances it will be noticed that the length of sewers per inhabitant varies from 1.71 in Dantzic to 2.86 in London.

### 1. *Cost of construction.*

A great uniformity is visible in the price per foot of all the works, and whatever deviations there are from the general average may be readily explained. Paris gives the highest figure, $9.62 per foot, which is due not only to the large sizes of the sewers, but also to the more costly shape and construction. Dantzic, on the other hand, gives the least figure, and this is due to the fact that much of the rain-water does not enter the sewers, but flows off on the surface into the numerous water-courses intersecting the city, thereby permitting of smaller sizes than would otherwise be necessary. Liverpool, likewise, shows a small figure, because about three hundred and fifty miles of small back drains are included, which in other cities belong to the house drains proper, and are paid for privately. Calculating their cost at $2 per foot and deducting them, the average cost of the remaining sewers would increase to $6.50 per foot, which is quite near to the general average.

The remaining cities show little difference. They are similarly sewered with the combined system, and the cost varies only from $5.68 to $6.10 per foot.

When reducing the cost of construction per inhabitant using the sewers, the results are also interesting. Confining ourselves to those cities where practically all properties are connected, such as London, System III of Berlin, Liverpool, Hamburg, and Dantzic, we find that in London, Berlin, and Hamburg, where sewers are similarly proportioned and designed, the expense varies only from $11.25 to $16 per inhabitant. In Dantzic, again, with its small sewers not carrying much rain-water, the cost has only been $6.25 per inhabitant, whereas in Liverpool it reaches about $19. If we also, at this place, make allowance for the back drainage, the cost is reduced to $13.60 per inhabitant. The high figure for Frankfort is, again, due to the circumstance that not all of the properties along the line of sewers are connected. When this is done the cost will be about $16.58 per inhabitant.

### 2. *Cost of maintenance.*

Paris, as might be expected from the elaborate system of flushing and cleaning, gives the highest figure—namely, 13 cents per foot—for maintenance. Vienna follows with 9.3 cents, one-third of which, however, is devoted to repairs. From the many old and ill-shaped sewers, the expense of keeping them in order would naturally be somewhat high. London averages 6 cents, Rad. System III of Berlin 4.3 cents, and Hamburg 3.6 cents per foot, all excluding pumping. The low cost in the latter city is due somewhat to the excellent flushing facilities, in making use of the Alster lakes and canals for this purpose. The cost of maintaining the sewers of Frankfort is 3.5 cents per foot. Here, too, the flushing by means of subsoil water, collected and stored at the highest points, facilitates the cleaning. In Liverpool, finally, the expense for this purpose is about 3 cents per foot, including back drains. The sewers have good grades and do not appear to need much cleaning. Their condition, however, judging from the odor arising at the ventilators in the higher parts, can hardly be as good as in the above-mentioned cities.

In reducing the annual cost of maintenance per inhabitant using the sewers, excluding pumping, the results are as follows: In London the expense is about 17 cents per head; in Liverpool, 14.7 cents; in Berlin, 10.1 cents; in Hamburg, 6.6 cents. In Frankfort, when all houses are connected, the figure will be about 10 cents, judging from the present cost. In Paris the present expense for maintaining sewers is 13.5 cents. In addition to this it costs 55 cents per head to remove the night-soil. In Vienna the expense of cleaning sewers is 7 cents per head, and for the removing of night-soil 10.5 cents per head in addition. The last two cities plainly show the great expense of dry removal, or the economy of water carriage for large cities requiring sewers for house and rain water.

Finally, a general induction seems to be indicated by a comparison of the cost of sewerage works.

It appears that the expense of a system per inhabitant increases with the size of the city. This is, in fact, what might be expected, as the cost of removing other refuse and of supplying the various needs of a community to its inhabitants usually shows a similar increase.

Herein lies, perhaps, one cause of the frequency of inferior draining arrangements in our large cities. While in a growing city we are always willing to increase the pay for immediate benefits, such as conveniences for our daily needs, we hesitate to increase it for what appear to be only remote benefits, such as the removal of waste matter. Only as the invisible dangers of the latter become distinctly recognized can it be expected that the proper proportion of money will be expended for it.

## VI. DISPOSAL OF SEWAGE.

Whereas comparatively little has been written on the previous subjects, there exists a considerable amount of literature on this one, owing mainly to the controversies that have arisen regarding it. I shall therefore merely state the conclusions to which the opinions of those engaged with the subject converge, and which a personal inspection of the various methods and works warrant, adding a few elucidating remarks.

I. The expectations entertained for a long time that town sewage could be converted into a valuable manure, which would not only pay for the conversion but render it profitable besides, have been given up, save by a few parties interested in patent processes. The general opinion held at present is that sewage must, beyond all other considerations, be disposed of in a way which is least injurious to the community, that a pecuniary profit cannot be looked for in every case, and that essential differences in topographical, physical, and geological conditions will require essentially different modes of treatment.

II. When sewage can be safely discharged into a large river or the sea, this will generally be the most satisfactory and economical mode of disposing of it. This method is practised in London, Vienna, Liverpool, Hamburg, and a large number of sea-coast towns, without presenting any objectionable features, care being taken that the sewage is not brought back to the towns by currents or winds. For tidal rivers it will be necessary to discharge it only at high tides and after, storing it during returning tide. Along the sea-coast it must be carried to a sufficient distance, so that the same end may be attained. Sea water offers greater difficulties in this respect than fresh water, as the sewage does not mingle with it as rapidly, floats on the surface for a long time, and is not as readily oxidized.

III. When sewage must be purified before it is discharged into a stream, the most satisfactory method is by means of *irrigation*, provided a sufficient amount of suitable territory and soil can be had at the price of good farming country.

The best examples of irrigation were found in Bedford, Doncaster, Croydon, Wrexham, and Leamington, in England; Dantzic and Berlin, in Germany, and in Gennevilliers, below Paris. The effluent was generally clear and in no way objectionable.

The soil for irrigation must be loamy, sandy, and porous. It must be deep-drained, and in such a manner that the sewage cannot reach the drains directly from the carriers. The quantity of land necessary varies with the soil, the season, and the crops, being one acre for one hundred to four hundred persons. A sewage farm requires not only much more attention than an ordinary one, but a considerable amount of skill. The most successful examples were those which received an intelligent supervision by specialists. The increased expenditure incurred through a sewage farm, however, can generally be covered in such cases by a greater abundance and better quality of the crops as compared with ordinary farms, especially when the soil in both cases is sandy.

IV. When sufficient land cannot be had for irrigation, on account of expense, &c., or during the winter months, when vegetation cannot absorb the sewage, *filtration* is sufficiently effective to purify it. During the winter it may be constantly applied; during the summer it should be intermittent. Examples are found at Kendal, Merthyr-Tydvil, and Abingdon, in England, and in the winter basins at Berlin.

The ground for this purpose must be a free soil, and the areas level, to allow the sewage to stand and gradually soak away. Here too, the entire ground must be deep-drained. The effluent observed at Kendal and Abingdon in summer was clear, tasteless, and without odor. In Berlin during December the effluent from the winter basins, in which the sewage was standing eighteen inches deep, was clear, but retained a strong odor. The amount of land used for filtration is one acre for four hundred to eight hundred persons.

Irrigation and filtration are frequently combined for the same town, and this is especially advantageous where the winter climate is severe.

V. Where land is not suitable for irrigation or filtration, or where none can be had on account of topographical conditions or expense, sewage can be purified by means of *precipitation* with sulphate of alumina or milk of lime, with subsequent filtration on a very small area, through prepared basins if possible.

England is the only country which furnishes examples of this method, the best of which are at Coventry, where the precipitant is sulphate of alumina, copperas, and lime, at Bradford, where it is lime alone, and at Aylesbury, where it is sulphate of alumina, clay, and charcoal, with a trace of blood. (A B C process.)

The effluents in each case are tolerably pure. The precipitate, or sludge, varies in value according to the chemicals employed. Lime gives it the least value, the Bradford sludge being given away to the neighboring farmers, who cannot even use it all. Sulphate of alumina is richer, yet at Coventry it does not command a ready sale. The Aylesbury sludge, owing to the large amount of animal charcoal added to it, has the greatest value, but it is at the same time the most expensive to produce. The expense of the precipitation varies with the particular method, the locality, and the degree of purity to be attained.—(See Robinson, "Sewage Disposal," London, 1880.)

VI. It may finally be said that an absolute standard of purity for the effluent should not be given, but that its degree should depend on local conditions, on the size of the sewer, on the use to which its water is thereafter to be put, and on the distance from the next town. In many cases it will even suffice to purify only a portion of the entire sewage of a town, the rest not being considered objectionable in the river. Although the cost of sewage purification is greatly modified by local conditions, it will be found in general to increase as land becomes less available or in the order given above. As the expense of land near a city generally increases in proportion to the size of the latter, the cost of purification per head of population will, *cœteris paribus*, be more expensive for large towns than for small ones.

Respectfully submitted.

RUDOLPH HERING,
*Civil and Sanitary Engineer.*

## APPENDIX NO. 1.

*Tabular arrangement of data relating to the sewerage works of eleven European cities.*

### SCHEDULE OF HEADINGS FOR EACH CITY.

A.—Statistics of locality.
  1. Population.
  2. Area.
  3. Number of dwellings.
  4. Water supply.
  5. Mortality.
  6. Meteorological.
  7. Topographical.
  8. Physical.
  9. Geological.

B.—Management of public works.

C.—Design and construction of sewerage works:

  I. General system and alignment.
  II. In streets, etc.
    1. Shape and size of sewers.
    2. Depths and grades.
    3. Junctions, connections, overflows, and outfalls.
    4. Ventilations.
    5. Man and lamp holes, and flushing shafts.
    6. Gullies.
    7. Pumping stations.
    8. Miscellaneous structures.
    9. Materials and construction.
    10. Statistics.
  III. In houses.
  IV. Disposal of sewerage.

D.—Maintenance of sewerage works.
  1. Appliances.
  2. *Method.*

E.—Cost of sewerage works.
1. Management and maintenance.
2. Construction.

CITIES: London, Paris, Berlin, Vienna, Liverpool, Hamburg, Frankfort-on-the-Main, Dantzic, Brighton, Oxford, Amsterdam.

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## LONDON.

### A.—STATISTICS OF LOCALITY.

#### 1. *Population.*

Drainage and water-supply district, 4,343,400. Average density, 55.6; varies from 42 to 174 per acre.

#### 2. *Area of metropolis.*

122 square miles=78,080 acres. Greatest length, 14 miles; greatest width, 8 miles.

#### 3. *Number of dwellings.*

In drainage district, 585,000. Number of inhabitants per house, average, 7.4.

#### 4. *Water supply.*

| | *Gallons.* |
|---|---|
| From rivers Lea, Thames, and chalk wells per day | 145,800,000 |
| From chalk wells, per day | 9,140,000 |
| From river Lea, per day | 61,989,000 |
| From river Thames, per day | 74,614,000 |
| | 145,743,000 |

81 per cent. used for dwellings; 19 per cent. for streets, fountains, &c. Average, 32.7 gallons per head. All river water is filtered.

#### 5. *Mortality.*

| | | | |
|---|---|---|---|
| 1840–1849 | 25.1 | 1850–1859 | 24.1 |
| 1860–1869 | 24.3 | 1870–1879 | 23.0 |

#### 6. *Meteorological.*

Temperature:

| | *Fahrenheit.* |
|---|---|
| Thirty years mean annual | 49.4 |
| Mean monthly maximum | 72.3 |
| Mean monthly minimum | 32.7 |

Maximum seldom above 80°, though it has reached 94°.
Minimum seldom below 15°, though it has reached —5°.
Mean daily range, 16.9; mean monthly range, 36.8 Fahrenheit.
Frost penetrates soil to a maximum of 2 feet.
Rain, annual, from 18 inches to 30 inches.
Thirty years' mean, 24.4 inches.
Number of rainy days per year, 170.
Mean humidity, 81.
Rain storms, maximum:

| | *Inches per minute.* |
|---|---|
| 1846, August, 3″.3 fell in $140^{m}$; 2″ in 30 minutes | .067 |
| 1852, July, 0″.5 in $15^{m}$ | .033 |
| 1857, October, 2″.92 in $36^{hrs}$ | .0013 |
| 1874, May, 0″.34 in $8^{m}$ | .043 |
| 1874, June, $0'^{hrs}$.96 in $30^{m}$ | .032 |
| 1874, July, 2″.23 in $84^{m}$ | .027 |
| 1878, June 23, 3″.00 (nearly) in $90^{m}$ | .033 |
| 1878, April 10 and 11, 2″.64 in $19^{hrs}$, maximum in $90^{m}$. | |
| 1880, July 14, 0″.36 in $12^{m}$ | .030 |

### 7. *Topographical.*

Situate on both banks of the Thames forty miles above its mouth. Largest area is on the northern bank, where the surface is above floods, slightly undulating and rising toward two prominent elevations (Highgate and Hampstead) near the northern municipal boundary. Southern bank is low, with districts below ordinary high water, gradually extending to high and hilly grounds near the southern boundary. Old water-courses of creeks are either sewered or kept free from pollution, such as the creek flowing through the "Serpentine." City datum: 12.50 feet below Trinity high-water mark. Average tide in Thames, 18 feet. At Barking and Crossness outfalls mean low water is —7.6: mean high water is + 10.72.

Extreme tides:

| | |
|---|---|
| 1874, March 20 | high water + 16.50 |
| 1874, April 18 | high water + 16.00 |
| 1874, October 21 | low water — 10.00 |
| 1875, November 15 | high water + 16.83 |
| 1877, January 2 | high water + 16.50 |
| 1877, January 31 | high water + 16.00 |
| 1877, October 8 | high water + 16.00 |

### 8. *Physical.*

Greater part of metropolis is closely built up, especially older portions of the center, north and south of river. West and northwest contain many open areas, parks, and gardens. Total length of streets is 2,600 miles, of which

1,338 miles are paved with macadam and partially granite blocks,
274 miles entirely with granite blocks,
23 miles with asphalt, and
15 miles with wooden blocks.

### 9. *Geological.*

The metropolis is underlaid by chalk, cropping out near Lewisham and Deptford. Above it are beds of pebbles, sands, clays, and loams (Lower London tertiaries) of varying thickness, more or less permeable and furnishing water supply. Outcrops are in the Isle of Dogs, Stratford, Dulwich, Peckham, Greenwich, and Woolwich. Above them is London clay, which underlies in varying thickness the greater part of London, and comes to surface in northern and southern parts. On this lies the valley drift, consisting of brick-earth, gravel, and sand. It forms the surface of a large part of the metropolis, and carries much water, which supplies all shallow wells. A small portion is built on alluvium, covering the former; and a few small districts are, more or less, built on made ground.

## B.—MANAGEMENT OF PUBLIC WORKS.

They are in charge of a *Metropolitan Board of Works* an elected body of forty-five members, each serving three years. The metropolis is divided into *vestries*, larger ones sending one representative and some two, smaller ones combining into *districts*, with one representative. The board is thus formed of representatives from twenty-four vestries and fifteen districts. Chairman is elected from their number. Duties consist in supervising all main public works, among which is the main drainage system in design, construction, and maintenance. Board levies rates and borrows money for their purpose. All main sewers are both designed and built by the board. Ordinary sewers in each vestry and district are built by *district boards*, which have each an engineer and surveyor, with necessary corps of assistants. But all their plans must previously be submitted to the Metropolitan Board for approval. Permanent staff of Metropolitan Board of Public Works, engineer's department:

Main office:
- 1 engineer in chief.
- 2 assistants to chief.
- 1 principal clerk.
- 16 engineers and draughtsmen.

Flushing staff:
- 5 inspectors.
- 8 clerks.
- 18 gaugers.
- 107 flushers.
- 36 sluice and flap keepers, mechanics, and laborers.

Pumping stations and outfall:
- 4 superintendents.
- 126 mechanics and laborers.

## C.—Design and Construction of Sewerage Works.

### 1. GENERAL SYSTEM AND ALIGNMENT.

Combined water-carriage with interception of sewage and slight portion of rain, at several levels, discharging it ten miles below city into the Thames at outgoing tides. The valley-line sewers, mostly old, receive excess of storm-water either direct or from overflows, and discharge by shortest line to the river. The Thames divides the system into two independent parts.

In the north there are three main intercepting sewers: The high, mid, and low level, and a few lateral branches, with final outfall at Barking. The high-level sewer begins south of Highgate, extends eastwardly to the valley of Hackney Brook, and crosses Victoria Park to Old Ford. The mid level begins near Harrow Road, passes under Paddington Canal, follows Uxbridge Road, Oxford street, Old street, Victoria Park, and joins the high level at Old Ford. These two sewers intersect all sewage that can flow into the Thames by gravity. A branch from the elevated grounds at Piccadilly joins the mid level. From Old Ford to Barking the two sewers are united in one embankment, built for them on account of the low grounds, and form the northern outfall sewer. At Barking a reservoir of 9½ acres, and 6,700,000 cubic feet capacity, collects and holds all the sewage during incoming tides. The low-level sewer begins at Pimlico, runs under the Thames embankment to Blackfriars, thence to Tower Hill and Abbey Mills, where its contents are raised 36 feet by steam-power, and discharged into the outfall sewer just mentioned. Several branches are connected with the low-level sewer, as follows: The Hackney, from the low grounds near the river Lea and the Isle of Dogs branch, both of which discharge into the low level at Bromley; also, the western low level, with branches from Acton, Chiswick, and Fulham, joining the main low level at Pimlico, into which its contents are discharged, after being lifted 17½ feet. South of the Thames there is a high-level and a low-level intercepting sewer, with final outfall at Crossness. The high level is formed of branches from the Crystal Palace, Upper Norwood, and Balham Hill, skirting the higher grounds and uniting at Deptford, and then continues its course to Crossness as the southern outfall sewer, where the sewage is raised 10 to 30 feet high into a reservoir, from which it is discharged during out-going tides. The low-level sewers, one beginning at Putney and the other at Bermondsey, unite at Deptford, where their sewage is pumped 18 feet into the outfall sewer just mentioned. When crossing these intercepting sewers, the old valley-line sewers are connected with them to take the storm-water overflow and lead it directly into the river. At present several extensive overflow sewers are being built in addition in various sections. The daily amount of sewage intercepted by the main drainage works is about 10,000,000 cubic feet north and about 4,000,000 cubic feet south of the Thames. The united capacity is 63,000,000 cubic feet, including a rainfall of ¼ inch in 24 hours. The system was designed by Sir J. W. Bazalgette.

### II. IN STREETS, ETC.

#### 1. *Shape and size of sewers.*

London exhibits a greater variety of shape in its sewers than any other city, representing as it does the ideas of several centuries. At present the following forms are used: Circular, for pipe sewers, which rarely exceed 18 inches diameter, and for certain intercepting sewers. The egg-shape is common for all brick and concrete sewers, except those for interception and storm-water. The oval form, having a larger invert radius, is used when a comparatively great ordinary flow is to be removed. Other forms, such as flat or slightly curved inverts, or railway tunnel sections, &c., are used for special purposes.

The sizes of sewers are partially calculated by formulæ, partially determined by other considerations. When providing for storm-water, Hawksley's formula is generally used. If A = acres drained and N = length in feet in which the sewer falls one foot, the log. diameter in

$$\text{inches} = \frac{3 \text{ log. } A + \text{log. } N + 6.8}{10}, \text{ assuming a rainfall of 1 inch per hour.}$$

When calculating the rain-water reaching sewers to be ¼ inch in 24 hours plus the sewage, which is done for the main drainage system, then Eytelwein's formula is used in the form:

$$\text{Vel. in feet per sec.} = \frac{9}{10}\sqrt{\text{mean hydr. depth} \times \text{twice the fall in feet per mile.}}$$

The amount of sewage calculated is one-half of daily amount, assumed at 34 gallons per head, therefore 17 gallons, to flow off in 6 hours.

The smallest sewers used are 9-inch pipes, but generally not less than 12 inches, in diameter. The smallest brick or concrete sewers are 2 feet by 1 foot 3 inches. In the City of London the ordinary sewers are usually of brick, 4 feet 6 inches by 3 feet, and 4 feet by 2 feet 6 inches, with a terra-cotta invert block of 10 and 12 inches radius. The northern high-level sewer ranges from 4 feet diameter to 9 feet 6 inches by 12 feet; the mid-level from 4 feet 6 inches by 3 feet to 12 feet by 9 feet 6 inches; the low-level from 6 feet 9 inches diameter to 10 feet 3 inches diameter. The southern high-level sewer ranges from 4 feet 6 inches diameter to 10 feet 6 inches diameter. The northern outfall has 3 sewers, each 9 feet by 9 feet, side by side. The southern outfall is 11½ feet diameter.

### 2. *Depth and grades.*

The depth of ordinary sewers below the street surface is from 12 to 15 feet. Cellars and basements are from 5 to 10 feet deep, and, if deeper, sewage must be raised into the sewer by the private parties. When a sewer for purpose of grade is over 16 feet deep, a second one is built above it, to receive house connections. Grades for sewers are usually limited to give a minimum velocity of 18 inches per second. Grades of

| | |
|---|---|
| Northern high level | 1: 71, then 1: 376, finally 1: 1100 |
| Northern mid level | 1: 300 to 1: 2640 |
| Northern low level | 1: 1760 to 1: 2640 |
| Northern outfall, 1,2640 (invert at outlet is 18 inches below high water). | |
| Southern high level | 1: 176 to 1: 2266 |
| Southern mid level | 1: 100 to 1: 2266 |
| Southern low level | 1: 1320 to 1: 2640 |
| Southern outfall | 1: 2640 |

### 3. *Junctions, connections, overflows, outfalls.*

Junctions of sewers are generally made by easy curves, but there is no uniformity in the details. They are generally covered by a funnel arch, and have a tongue between the sewers. The chamber has a ventilator to the surface. House connections to sewers are made at an angle, either by blocks or slant pipes set into the brickwork. They are generally placed into the sewers when built. Overflows vary in design, and are generally placed at three-fourths of height of sewer. The mouth is wide, to take the water freely, and is then reduced to a circular or egg-shaped channel. Outfalls of main drainage sewers are at Crossness and Barking. At the latter sewage discharges by gravity. It is stored in covered reservoirs of 9½ acres, and discharged only during outgoing tides. At Crossness the sewage is pumped into reservoirs of 6½ acres, from which it is discharged also during outgoing tides.

### 4. *Ventilation.*

Sewers are ventilated by frequent openings into the street, generally by special shafts 6 inches, 8 inches, 10 inches, or 12 inches in diameter, terminating in the side of a basin, which is covered by an open grating. Man-holes are also often ventilating. Ventilation through soil-pipes is not generally indorsed, a disconnecting man-hole between sewer and house with an open grate being preferred. Formerly the furnaces and stacks at pumping-stations were made use of for ventilation; but this is now abandoned, as it checks the draft, and is not efficient except for a short length of sewer. The odor in the old London sewers is very strong as a rule; in the newer ones it is much less so. In a concrete sewer at Camberwell, built thirteen years ago, in which the sides are smooth and clean and the sewage was running swiftly, there was a scarcely perceptible odor six or seven days after the flushing. The odor at the pumping-stations is very slight, if at all noticeable, and is never objectionable. It is greatest when sewage runs very low—greater in dry than in wet weather, greater on Sundays than in the week. A very strong smell is always found at the screens where the floating solids are taken out; but the men who have been engaged at this work for many years remain quite healthy.

### 5. *Man and lamp holes and flushing shafts.*

Man-holes are mostly built with side entrances, especially in the central portion of the metropolis, having either vertical shafts or steps. When in the street, they are circular, and usually 2½ to 3 feet in diameter, covered with a grating, partially open and partially with inserted blocks of wood to deaden the noise of passing wheels. The entrances, when on the sidewalk, are closed by a tight-fitting cover, which, when the man-hole is in use, remains raised up, and the opening is protected by an additional grate. The new man-holes for pipe-sewers are without a "drop" or basin, the pipe being carried through it, with a slightly increased fall, in semicircular sections, either straight or curved. Lamp-holes are 6 inches to 12 inches in diameter, and are occasionally used on pipe-sewers at bends. When ventilation is required a small basin to catch the street dirt is placed beside the shaft of the man or lamp hole, and through this the air passes out. It is about 9 by 18 inches, and is covered by an open grate, while the man-hole cover has no openings. Special shafts for flushing are sometimes placed at the upper ends of the pipe-sewers, and resemble the lamp-holes, but have a basin at the bottom to hold at least a cubic yard of water. Resting places for workmen are occasionally built on small sewers, 6 feet high and 6 feet long. They are ventilated.

### 6. *Gullies.*

The gullies are commonly placed under the gutter, the inlet being covered by a grating 16 by 18 inches, hinged. They are generally 4 feet deep and have almost always a catch-pit and a trap. The pipe leading to the sewer is 6 inches or 9 inches diameter. The trap is formed sometimes by a flag-stone 3 inches thick, let down from the top and sometimes by the outlet-pipe itself. The seal is about 12 inches. The grating has bars 1¼ by 4 inches deep, with spaces of 1¼ inches. They are not located at the street corners, but in the blocks, generally 200 to 300 feet apart. Some inlet-basins are of iron 22 by 21 inches and 3 feet below the grating. There are a few inlets which lead directly into the sewer without trap or basin, by 9-inch terra-cotta pipes.

### 7. *Pumping-stations.*

London has four large pumping-stations. They are at Deptford and Crossness on the southern side, and at Pimlico and Abbey Mills on the northern side of the Thames. The Deptford station is the oldest, having been in use 17 years. The sewage is raised 18 feet from the southern low-level sewer into the outfall. The inlet is a twin sewer, each 7 feet in diameter. The ordinary depth of water in them is 4 feet. There are 4 engines, each 125 horse-power. Amount of sewage which can be raised is 13,728 cubic feet per minute. The Crossness station is situated at the southern outfall. The sewage is raised from 10 to 30 feet either directly into the Thames or into storage reservoirs, of which there are 4, each holding 6,000,000 gallons, and covering together 6¼ acres. The tide runs out 7 hours. Gates are left open 1 hour before to 4 hours after high tide. There are 4 engines, each 125 horse-power, driving 32 pumps and lifting ordinarily 106,400 gallons per minute. Diameter of pumps, 4½ feet. Four have a stroke of 4 feet, and four have a stroke of 2 feet. The works are being extended. Amount of sewage which can be raised per minute is 17,028 cubic feet. The Abbey Mills station is situated on the line of the northern high level, where the sewage from the northern low level is pumped into it 36 feet high. The diameter of the inlet sewer is 10 feet 3 inches. There are 8 engines, each 142 horse-power, driving 16 double-acting pumps, raising ordinarily 96,000 gallons per minute. The amount of sewage which can be raised per minute is 15,000 cubic feet. The western pumping-station (Pimlico) is the most recently built. Here the sewage from west of Chelsea is raised into the northern low-level sewer. The inlet is 6 feet 9 inches diameter, with an ordinary depth of sewage of 3 feet. The left is 17.8 feet (—19 to —1.20 below datum). During heavy storms the sewage is pumped into the Thames. There are 4 engines, each 90 horse-power, with a supplementary engine 120 horse-power. The engines drive 2 pumps each, of 5 feet 3½ inches diameter and 4 feet stroke. Six thousand cubic feet of sewage can be raised per minute. In 1878 the engines at work, representing 2,620 nominal horse-power, consumed about 23,340 tons of coal.

### 8. *Miscellaneous.*

* * * * * * *

### 9. *Materials and construction.*

Materials used for sewers are brick, concrete, and terra-cotta pipe. Bricks are of the best stocks; the inverts are often built of or lined with Staffordshire blue bricks. Wedge-shaped bricks are generally used in small sewers. The arches of sewers up to and including 2 feet diameter have a thickness of half-bricks (4½ inches); invert masonry is always 9 inches thick. The inner surface of lately-built brick sewers presents a very even and smooth appearance. Concrete is preferred where not too expensive. Portland cement is used for it in proportions of 1:4 to 6 of Thames ballast (gravel and sand mixed), and allowed to set one week before centers of large sewers (6 by 4 feet) are drawn. Concrete sewers many years old presented a perfect condition with very little adhesion of sewage particles, and very little odor. Sometimes concrete sewers are lined with a 4½-inch ring of brick. Pipe-sewers are very carefully laid; when ground is at all uncertain they are laid in a bed of concrete 6 inches thick all around the lower half. Stanford's patent joint is frequently used.

Mortar is made of Portland cement and a sharp, washed sand in proportions of 1:1 and 1:3, the former for inverts, the latter for arches. A yearly contract is given out for all work under £500. For larger amounts special specifications and contracts are made. All work is usually given out for a certain sum, with prices attached for variations of original quantities.

Before 1846 no sewers were egg-shaped, none were built of vitrified pipe, and none of half-bricks.

### 10. *Statistics.*

| | | | |
|---|---|---|---|
| Ludgate Hill sewer was built before the year | | | 1668 |
| Fleet street sewer was built in | | | 1668 |
| First surveyor for London was appointed in | | | 1768 |
| Length of sewers: | | | |
| Up to 1855, inclusive | miles | | 1,146 |
| Up to 1856–1877, inclusive: | | | |
| Main drainage | | 82 | |
| District sewers | | 857 | |
| Reconstructed sewers | | 56 | |
| | | | 995 |
| 1878 to 1880, inclusive | miles | | 135 |
| Total length of sewers | miles | | 2,276 |
| Of which 550 miles are of vitrified pipe. | | | |
| Intercepting sewers: | | | |
| Northern high level, length | miles | | 7½ |
| Area drained | square miles | | 10 |
| Northern mid level, length | miles | | 9½ |
| Piccadilly branch, length | miles | | 2¼ |
| Area drained | square miles | | 17½ |
| Northern low level, length | miles | | 8½ |
| Hackney branch, length | miles | | 2⅛ |
| Isle of Dogs branch, length | miles | | 1⅞ |
| Area drained | square miles | | 11 |
| Western extremity of northern low level, length | miles | | 5⅛ |
| Fulman branch, length | miles | | 1⅛ |
| Acton branch, length | miles | | 1⅝ |
| Area drained | square miles | | 12½ |
| Northern outfall sewer, length | miles | | 5½ |
| Southern high level, length | miles | | 5⅝ |
| Effra branches, length | miles | | 7½ |
| Area drained | square miles | | 20 |
| Southern low level, length | miles | | 9½ |
| Bermondsey branch, length | miles | | 2¼ |
| Greenwich and Deptford, length | miles | | 1⅞ |
| Area drained | square miles | | 20 |
| Southern outfall sewer | miles | | 7½ |
| Area drained, additional | square miles | | 2 |

Daily amount of sewage discharged into Thames from both outfalls, 17,600,000 cubic feet.

Deptford pumping-station was opened 1864.
Crossness pumping-station was opened April 4, 1865.
Abbey Mills pumping-station was opened July 30, 1868.
Western (Pimlico) pumping-station was opened August 5, 1875.
Number of gullies in 1878, was 67,491.

### III. IN HOUSES.

No uniform system or regulations. The majority of houses (the older ones) are said to be improperly drained or connected with sewers. Lately plans are being submitted to the vestries for approval showing lines of pipes, closets, sinks, &c., on a scale of 8 feet to 1 inch.

Inspection shafts, disconnecting chambers, or man-holes are preferred between the house and street sewerage, so that no gases from the latter can enter the house pipes.

These are usually outside of walls, especially the soil-pipe. Water-closets are said t be in every house, and cess-pools entirely abolished. Each receptacle of sewage i trapped. The following principles are recommended by authorities:

Pipes shall be of iron with leaded joints or of glazed stoneware, with socket-joints filled by cement. Neither shall be less than 4 inches diameter. Grade, if possible, 1:20 never less than 1:40. Drains are never to be under buildings unless embedded in concrete 6 inches all round and ventilated at each end. All branches must join obliquely in direction of flow. Every inlet is to be trapped, and every pipe trapped as near as possible to sewer. Two untrapped openings for ventilation, to be as far as possible apart, one near the ground, and the other, not less than 4 inches diameter, carried up at least 10 feet above ground or building. Soil-pipe to be carried up outside of building full size beyond the roof. No container or D-trap should be used. Waste-pipes, except from slop-sink, must not be connected with soil-pipe or pass to the drain, except first through a gully outside the building, and which is trapped against and disconnected with the sewer. It is to have an open grate or be specially ventilated. No drain connected with any cess-pool should be connected with any pipe leading to sewer.

### IV. DISPOSAL OF SEWAGE.

The metropolitan sewage is discharged into the Thames at Barking and Crossness, 10 miles below the city. It is temporarily stored in reservoirs during incoming tides. Velocity of water in Thames, average, 4½ inches per second.

| | Reservoir. | | Discharge. | |
|---|---|---|---|---|
| | Area. | Capacity. | Daily sewage. | Maximum rain fall. |
| | *Acres.* | *Gallons.* | *Cubic feet.* | *Cubic feet.* |
| Barking | 9½ | 45,000,000 | 11,600,000 | 28,500,000 |
| Crossness | 6½ | 24,000,000 | 6,000,000 | 17,200,000 |

## D.—MAINTENANCE OF SEWERAGE WORKS.

### 1. *Appliances.*

Sewers are cleaned generally by flushing. Old sewers with flat inverts, and new ones when accidental obstructions occur, are entered and cleaned with scrapers and shovels. Pipe-sewers, when they become obstructed, are cleaned with circular brushes drawn through them, or by jointed hooks, which are closed when pushed in, and are forced open by a spring when drawn back. For flushing the pipe-sewers, either flap-valves are used or such as work in a groove, regulated from above to dam the sewage or flushing water. Large sewers have pen-stocks inserted at necessary intervals. They are generally worked from above, and consist of a heavy door either drawn upward or swinging to one side. The pumping stations also have pen-stocks to hold the sewage back temporarily or to regulate the discharge into the river or to the pumps.

The gullies are cleaned regularly and often. The scoops used have a flat or semicircular bottom.

### 2. *Method.*

Prior to 1871 the cleaning of the main valley-line and intercepting sewers (about 250 miles) was done under contracts. After careful inquiry it was then decided to have it done by a staff of men appointed by and under the direction and control of the board. (See B.) Ordinary sewers are maintained by the district boards and vestries. The sewers are regularly inspected at different intervals, and flushed or cleaned when necessary.

In 1878 there were taken out of sewers 723,000 cubic yards deposits. In 1878 there were taken out of gullies 100,050 cubic yards silts.

Every year a contract is given out for repairs or new works under £500 in value. Special contracts are made for works over this amount.

COOPER
MEDICAL
COLLEGE.

## E.—COST OF SEWERAGE WORKS.

### 1. *Management and maintenance.*

| gineer's department for 1879. | Number of employés. | Total salaries. |
|---|---|---|
| ain office | 32 | £12,200 |
| ping stations | 127 | 11,186 |
| e and flap keepers | 48 | 3,493 |
| s of works, &c. | 10 | 1,822 |
| hing inspectors, foremen, and men | 144 | 10,301 |
| rmen, &c. | 10 | 790 |
|  |  | 39,790 |
| bout |  | $195,000 |

*Cost of pumping stations for* 1879.

|  |  |
|---|---|
| es | £9,689 |
| l | 18,204 |
| irs | 8,098 |
| ellaneous | 2,870 |
|  | 39,041 |
|  | $191,000 |

*Cost of sewerage works under metropolitan board in* 1879.

|  |  |
|---|---|
| es of inspectors, sluice and flap-keepers | £4,000 |
| struction | 2,200 |
| airs (including hedging and ditching at Barking) | 7,215 |
| nsing (including wages) | 14,550 |
| dentals | 630 |
| ilation and deodorizing | 350 |
| t and taxes | 120 |
|  | 29,065 |
|  | $142,400 |

tal cost of maintaining sewerage works under metropolitan board, including en- er's department, £80,000 = $392,000.

unicipal expenses are paid out of a rate, a tax upon real estate. It is about $3.25 he $100. The maintenance of all the London sewers costs about 25 cents per l per annum, including pumping, which is about 8 cents per head.

### 2. *Construction.*

ain sewers are constructed by the board and are paid for out of rate. Small sew- ure generally paid for by the private parties benefited, and the greater number also built by them. The total amount of money applied by the board to intering sewers and main sewers since consolidation has been £5,607,435 = $27,500,000. includes 82 miles of main intercepting drainage and 58 miles of main valley-line ers, making 140 miles. Average cost of main drainage per mile is $280,000; of the n valley-line sewers per mile, $65,000. The cost of the western (Pimlico) pumpstation was $900,000, including ground, of which $283,000 were for boilers, pumps, engines.

## PARIS.

### A.—STATISTICS OF LOCALITY.

#### 1. *Population.*

1880, 2,100,000; average density, 96 persons to 1 acre; the old city has as many 3 to 1 acre; the outer districts, Gobelins and Observatoire, 45 and 61, respect- r, per acre.

#### 2. *Area.*

|  |  |  |
|---|---|---|
| le of fortifications | acres.. | 19,281 |
| umference, 33,330 meters, or over | miles.. | 20 |

| | | |
|---|---|---|
| Greatest breadth from north to south | miles.. | |
| Greatest breadth from east to west | do ... | |
| Areas covered by public streets | acres.. | |
| Areas covered by rivers or quays | do ... | 1 |
| Areas covered by cemeteries | do ... | |
| Houses, parks, and gardens | do ... | 14 |

### 3. *Dwellings.*

Number of private houses, 74,740, containing 685,000 dwelling rooms and 33 shops and work-rooms. Number of inhabitants per house, 30.8.

### 4. *Water supply.*

Average per day:

| | | |
|---|---|---|
| Watering and washing streets | gallons.. | 28,713 |
| Watering and sprinkling parks | do.... | 9,477 |
| Fountains | do.... | 10,70 |
| Public buildings, hospitals, &c | do.... | 11,474 |
| Private dwellings | do.... | 33,141 |
| Total | do.... | 93,514 |
| Minimum | do.... | 78,714 |
| Maximum | do.... | 104,600 |

This quantity is divided up as follows:

| | | |
|---|---|---|
| Vanne (spring) | gallons.. | 26,414 |
| Dhuys (spring) | do.... | 6,60 |
| Ourcq (creek) | do.... | 34,33 |
| Marne (river) | do.... | 13,207 |
| Artesian wells | do.... | 184 |
| Seine (river) | do.... | 23,77 |
| Supply not sufficient; it is desired to have | do.... | 132,000 |
| Present average, per head | do.... | |
| Present average, per head of spring water (Vanne and Dhuys) which is intended for house supply only. | do.... | |

### 5. *Mortality.*

Mean for ten years.................................................
In VII Arrondissement (Elysée) it is.................................
In XIII Arrondissement (Gobelin) and XIV (Observatoire)..................

### 6. *Meteorological.*

Temperature:

| | Fahren |
|---|---|
| Sixty years mean | +5 |
| Highest known temperature, August 26, 1765 | +10 |
| Lowest known temperature, January 25, 1795 | —1 |
| Mean of yearly maximum for 180 years | +9 |
| Mean of yearly minimum for 180 years | +1 |
| During last 90 years average number of days in a year when the thermometer was below freezing | |
| During last 90 years average number of consecutive days of frost per year. | |

Depth of frost: Mean, 8 inches; maximum, 31 inches.

Rain:

| | |
|---|---|
| Mean annual | inches.. |
| Minimum annual, in 1733 | do.... |
| Maximum annual, in 1804 | do.... |
| Average number of days per year when rain falls is | |
| Mean humidity | |

Maximum rain storms: In summer often ⅘ inches fall per hour.

1860, July 16, 38 millimeters in 20 minutes = .0750 inch per minute.
1865, May 23, 26 millimeters in 20 minutes = .0520 inch per minute.
1866, July 16, 32 millimeters in 30 minutes = .0424 inch per minute.
1867, September 20, 41 millimeters in 20 minutes = .0810 inch per minute.
1870, May 22, 26 millimeters in 60 minutes = .0172 inch per minute.
1872, July 27, 40 millimeters in 60 minutes = .0263 inch per minute.
1879, August 15, 16.3 millimeters in 40 minutes = .0164 inch per minute.

*Prevailing winds*, southwet.

### 7. *Topographical.*

tuate on both banks of the Seine, 110 miles in a direct distance from its mouth
a little below its confluence with the Marne. Largest part of the city is on the
hern bank. This is also more undulating than the southern. The highest points
The Places de Montmartre, de l'Etoile, du Roi de Rome, the Buttes Chaumont,
the heights of Belleville. The south side falls more gradually to the river, with
average slope of 1 : 130. Altitude of the Seine at Paris is 80.5 feet above the sea.
part of the city is flooded by high water; both shores have stone embankments
ugh the city. Fall of river at low water when discharge was 1,695 cubic feet per
nd : for eastern extremity of Paris, 1 : 19,483; for center of Paris, 1 : 1,243; for west-
extremity of Paris, 1 : 14,225. Flood discharge March, 1876 (highest), was 56,500
ic feet per second.

### 8. *Physical.*

der part of city is very closely built up, especially toward the north and south.
western part has broad streets, avenues, parks, &c. Length of streets, boule-
, &c., is: with trees, 136 miles; without, 415 miles. Area covered by streets,
A 2.

## B.—MANAGEMENT OF PUBLIC WORKS.

All public works are under control of an inspector general and director, with a gen-
office and corps of 26 persons. The main departments, each one of which has a
f engineer and a large corps of assistants, are as follows:

*Streets.*—For the general design and laying out of the city, its streets, parks,
; also for the registry of real estate property; also for the construction and clean-
of streets. Corps: 45 persons for design and registry; 314 persons for supervision,
truction, and maintenance.

I. *Lighting the city.*—Corps: 50 persons for design, construction, and supervision.

III. *Parks and boulevards* (landscape gardening).—Corps: 165 persons for design
maintenance.

IV. *Water supply and sewerage.*—Corps for general offices: 211 persons for design,
struction, and maintenance.

Water-supply: Chief engineer and corps.

Sewers, canals, and sewage farm: Chief engineer, consulting engineer, and corps
general work; especial engineer for construction and maintenance of sewers and
htsoil service, with corps; special engineer for disposal of sewage and nightsoil,
h crops.

. *Tramways.*—For construction and service of passenger railways of the city.

I. *Architecture.*—For construction and maintenance of all public buildings, 13 con-
ting architects, 12 regular architects, 60 inspectors, &c.

### *Paris Budget for* 1881.

| | | |
|---|---|---|
| Ordinary expenses: | | |
| | | Francs. |
| terest on municipal debt, &c | | 99,308,308 |
| lice | | 22,820,568 |
| blic schools | | 15,343,118 |
| blic charities and pensions | | 16,202,973 |
| ntribution for maintenance of army | | 2,944,800 |
| terments | | 1,135,308 |
| Public works: | | |
| neral office | 1,717,600 | |
| chitecture and fine arts | 4,669,200 | |
| blic highways | 22,312,050 | |
| omenades and lighting | 8,901,980 | |
| ater and sewer department | 11,446,460 | |
| | | 49,047,290 |
| her expenses | | 22,893,088 |
| Total | | 229,695,453 |
| Extraordinary expenses: | | |
| w streets and pavements | | 2,480,000 |
| w buildings | | 3,960,000 |
| her expenses | | 4,040,000 |
| Grand total | francs.. | 237,295,453 |
| | or.. | $47,479,091 |

## C.—Design and Construction of Sewerage Works.

### I. GENERAL SYSTEM AND ALIGNMENT.

Transitional state at present. Four-fifths of all excrementitious matter is collected in water-tight vaults (fosses fixes) or in movable casks (fosses mobiles) and is periodically removed to a distant locality. The remaining quantity, which is increasing, is collected in casks (fosses filtres) which retain solids but permit liquids to escape and flow into sewers. They are exchanged at less frequent intervals and their contents disposed of in a similar way. All waste water from houses and streets, together with rain, are carried into a system of sewers. Its extent, as a uniform system throughout, excels that of any other city. Paris is divided into three main drainage-areas, from which the sewage is carried entirely out of the city, and each one of which has a main collecting or intercepting sewer (collecteur général). The northeastern area is drained by the Collecteur du Nord, which begins near the Père la Chaise cemetery, passes the Buttes Chaumont and Montmartre, and terminates in two branches, one at St. Ouen and one at St. Denis. At St. Ouen it has an elevation which permits the sewage to flow across the Seine and to the irrigation fields at Gennevilliers by gravity. The central and main area is drained by the Collecteur d' Asnières, which begins at the arsenal in the east of Paris, follows the right bank of the Seine to the Place de la Concorde, and then crosses through the city to Clichy, where its contents are now partially (and will be entirely) pumped with a head of thirty feet through cast-iron mains to the irrigation fields between Asnières and Gennevilliers. The southern area, consisting of the entire city south of the Seine and the eastern end of the city north of it, is drained by the Collecteur de la Bièvre, which begins back of the Jardin des Plantis, follows the left bank of the river to the Pont de l'Alma, crosses it there by an inverted siphon, and joining the Collecteur d'Asnières at Levallois-Perret, discharges at Clichy, respectively on the irrigation fields. Besides these main collectors there are about sixteen secondary ones discharging into them. The remaining are the "ordinary" sewers. In all streets above 65.5 feet in breadth double lines of sewers are built, one under each sidewalk, and in narrower streets they are built in the center. The ordinary sewers follow the valley lines as much as possible, and are all large enough to be walked through. No pipe sewers are used. The entire system was designed by M. Belgrand.

### II. IN STREETS, ETC.

### 1. *Shape and size of sewers.*

The smaller or ordinary sewers have a shape approaching the oval, but with a flat egmental invert, varying from 16 to 24 inches in width. The larger sewers or colsectors have a banquette on one or both of the sides of the invert (cunette) high lenough to be above the ordinary flow and broad enough to be walked upon. The main collectors have an invert about 11 feet wide and 4½ feet deep, in which specially constructed cleaning boats (bateaux vannes) are floated. The secondary collectors have inverts 47½ inches wide and 31 inches deep, with iron rails at their edges upon which the cleaning-trucks are run. The arches of the sewers covering the invert (cunette) and banquettes are semi-circular. All sewers are built large enough for men to walk upright in them, even the house branches, which extend to the point where the vertical soil and other pipes descend. Pipes for the water-supply, pneumatic tubes, and telegraph wires are inside of the sewer and attached to the arch. The sizes are divided into various types numbered from 1 to 14 for the sewers, and from 1 to 3 for the house branches. The main dimensions are as follows, all in meters.

*Sewers.*

| Number of type. | Height under key. | Width at spring. | Sectional area. | |
|---|---|---|---|---|
| 1 | 4.40 | 5.60 | 18.76 | Main collectors with foot-paths. |
| 2 | 5.35 | 5.20 | 16.59 | |
| 3 | 3.90 | 4.00 | 11.81 | |
| 4 | 2.98 | 3.70 | 9.89 | Secondary collectors with path and rails. |
| 5 | 3.80 | 3.00 | 8.66 | |
| 6 | 3.15 | 2.50 | 7.04 | |
| 7 | 3.55 | 2.50 | 6.29 | |
| 8 | 2.80 | 2.30 | 5.02 | |
| 9 | 2.75 | 2.00 | 4.23 | |
| 10 | 2.40 | 1.75 | 3.24 | Ordinary sewers, oval. |
| 11 | 2.30 | 1.30 | 2.36 | |
| 13 | 2.10 | 1.30 | 2.15 | |
| 13a | 2.00 | 1.05 | 1.65 | |
| 14 | 2.00 | .90 | 1.44 | |

*House branches.*

| Number of type. | Height under key. | Width at spring. | Width at bottom. | Used when length is— |
|---|---|---|---|---|
| 1 | 1.80 | 0.90 | 0.60 | Over six meters. |
| 2 | 1.40 | 0.60 | 0.40 | Between 2 and 6 meters. |
| 3 | 1.00 | 0.60 | 0.40 | Two meters or less. |

The selection of a type for a certain locality is governed by the following considerations: When the grade is heavy, *i. e.*, over 1 to 100, the types Nos. 10 to 14 are considered sufficient to discharge any water that may enter them in any of the drainage areas. When the grades are small, the type is determined through the following formula, which is derived from Prony's formula: Mean radius × slope = coeff. × square of velocity, and the assumption that the greatest quantity of rain falling in Paris is 1.77 inches per hour and the time to reach the sewers is three times longer than the duration of the rain.

$A$=drainage area; $a$=section of sewer; $r$=mean radius; $s$=fall per 1,000, all in metric measure;

$$a=\frac{0.0239A}{\sqrt{rs}}.$$

When storm-water overflows can be had, proper allowance is made when using this formula.

### 2. *Depth and grades.*

The depth of the ordinary sewers, unless grade demands it otherwise, is regulated so that they get a covering of at least 20 inches, which brings their inverts at least 6 feet below the surface. The depth of the invert (cunette) is at least 1 meter for the types cleaned by boats and at least 31¼ inches for those cleaned by the trucks. The grade of the ordinary sewers is generally the same as that of the street; it is often rather steep. The large collectors are very flat and are not self-cleaning, owing to the large amount of silt which is washed into them from the streets. Types 1 and 3, which are cleaned by boats, have a fall from .0003 to .0005. Types cleaned by the flushing trucks can have grades as low as .0005, and as high as .005, beyond which their action is impaired. Sewers without rails that receive little water must have a fall of at least .002, but can be as steep as .05, and in short lengths even .08. It is preferred not to have a greater fall than .04. The sewers without rails are to be made as short as possible, so that the sediment can readily be pushed down to a sewer with trucks or boats, instead of being taken out on to the street. The grades of the Collecteur d'Asnières are from .00125 to .00036; Collecteur de la Bièvre, .001 to .00034; sewer on the Boulevard de Sebastopol, .00068; sewer on the Rue de Rivoli, .00066 to .00024; sewer from Hotel de Ville, .000307 for nearly 4,000 feet. The ordinary grade for house branches is 0.03.

### 3. *Junctions, connections, overflows, outfalls.*

The junctions of large sewers are not made in the English or Frankfort manner, but as a rule rectangular chambers with cylindrical arch. The curves of the types cleaned by boats must have a least radius of 197 feet; those cleaned by trucks on rails, 98 feet. In the latter case, if this radius cannot be had, the line may be broken and a turntable inserted for the truck. This is to be avoided, however, if possible. Sewers without rails may be joined at any angle. Whenever possible an extra fall is to be given at every junction, so that no backwater is caused in the smaller sewer. The grade of large sewers at their junctions is also determined by the necessity of having the banquettes on the same level; the cunette or invert will therefore drop correspondingly. When sewers without banquettes discharge into sewers with banquettes, their inverts must be 10 to 12 inches below the level of the latter. When two oval sewers join, a drop of 8 to 12 inches is given, if possible, to each. The highest ends of the sewers are placed as little below the surface as allowable. The house branches, at least 1 meter high, connect with the sewers generally at right angles, which does not seem objectionable, as the house sewage is usually brought to the main in terra-cotta pipes, bedded in the invert of the branch and discharged from a trap-basin (cuvette.) These pipes receive the house water and the fluid excrements of the "fosses filtres" where these are used. The branches from the sewer extend under the sidewalk and often under the houses to the back yards. Storm-water overflows are placed along the river at a few places. There are three outfalls for the Paris sewage: one at Clichy, one at St. Ouen, and one at St. Denis, all on the banks of the Seine several miles below Paris. The outfall at St. Ouen is at an elevation to allow the sewage to run by gravity to the irrigation fields of Gennevilliers. The sewage from the lower areas discharges at Clichy at ordinary high-water level, and its contents are now partially being pumped to Asnières, Gennevilliers, &c. Arrangements are being made to pump all of the sewage in the future.

### 4. *Ventilation.*

The Paris sewers are ventilated through the street-gullies and the outfalls, and occasionally through pipes terminating at roofs of buildings. No objectionable odor arises from the gullies into the street, nor is there much smell in the sewers, except from some irregularity, which is quickly removed. The most noticeable sources of bad odor are the street-inlet branches, where the silt often lies several days before it is removed.

### 5. *Man and lamp holes, flushing shafts.*

Man-holes (branchements de regard) are always entered on the sidewalks, through side entrances to the sewer, never from the street. They are closed with a cast-iron cover, 2 feet 7½ inches in diameter, and are descended by iron steps, fixed in the wall every foot. The floor of the side entrance is, ordinarily, 1 foot above the invert of the sewer, and slopes toward it with a grade of 0.015. Sometimes, in larger sewers, carrying much water, stone steps are built instead. The height of the passage way is 6 feet 7 inches, its width at spring is 39 inches, at bottom, 20 inches. There are no lamp-holes or flushing-shafts. Man-holes are, generally, 164 feet apart, which is not varied from, except when near a sidewalk crossing.

### 6. *Gullies.*

Gullies (branchements de bouche) have side openings in the curbs, 39 inches long and 4 inches to 5 inches high in the center and 2 inches at the sides. The curbstones are about 11 inches wide at the top, with a face batir of 1 inch. The depth of the gutter at the inlet is 6 inches to 8 inches; elsewhere it is from 3 inches to 6 inches. The water drops into a shaft, measuring 18 inches in the direction across the street and narrowing at right angles to it, from 39 inches to 20 inches at 5 feet below the surface. The branch to the sewer then slopes down to about 8 inches above the invert, with a width of 20 inches at the bottom, and is covered by a horizontal, semicircular arch, with a span of 31½ inches, joining with the arch of the sewer. The junction of the branch with the sewer is made so that the upper side is brought in at right angles to it, the lower one being curved with a radius of 5 feet to prevent the currents from meeting at right angles. The latter precaution is, however, not required for the largest types. In a few instances the gullies have catch-basins, (reservoirs de sable.) Such basins are only in the suburbs and at the highest parts of the drainage areas. Gullies are built at no regular distance. The flatter the grade the more frequently they are placed. They are not located at street corners, but in the block.

### 7. *Pumping-stations.*

The pumping station is situated at Clichy, near the bridge crossing the Seine to Asniéres. Its capacity is gradually being extended to correspond with the extension of the irrigation fields. The present works provide for only one-sixth of the sewage. There are two horizontal engines, one of 250 horse-power, the other of 150 horse-power. The larger one works two centrifugal pumps 71 inches diameter, one lifting the sewage 16½ feet, the other forcing it to an additional head of 20 feet. The smaller engine works two centrifugal pumps, 47¼ inches diameter. The larger engine raises 1,040,000 gallons per hour, in a day of fifteen hours, at a cost of 52 cents per 1,000 gallons raised 36 feet, with coal costing $6.30 a ton.

### 8. *Miscellaneous structures.*

The sewage crosses from the south to the north side of the Seine by an inverted siphon near the Pont de l'Alma. It is a double line of wrought-iron tubes each 1 meter diameter (39⅜ inches), 556⅜ feet long, laid several meters below bottom of river. The head upon the siphons can be varied from 1.7 feet to 7.8 feet as it becomes necessary. No trouble has been experienced with it.

### 9. *Materials and construction.*

Sewers are built of bowlders of a coarse, gritty sandstone (*meulière*), found in neighboring diluvium. Lately, some have been built of concrete. Bricks are rarely used. Vitrified pipes are only used for house drainage. The *meulière* masonry, bedded at right angles to the inner surface, is plastered with rich Portland cement mortar to an exceedingly smooth and regular surface. The coating must have a thickness of at least ¾ inch over the most projecting points of the masonry. The least thickness of coating of the invert and banquettes must be 1¼ inches; the coating of the extrados of the arch must be ¾ inch. The stones form only about 50 per cent. of the bulk of the masonry, and are intended to act rather as stones forming a concrete than to give much strength in themselves. The underground sewage carriers in Gennevilliers are built entirely of concrete; their strength is tested to a head of 26 feet of water. The material is composed of 3 parts cement to 5 parts clean gravel and 5 parts sand in volume. The concrete sewers are partially molded in the trench, and partially molded at the works and joined in the trench. The cement ordinarily used is the "Vassy"; the mortar is mixed in proportions of 1 part cement to 3 parts sand, and 2 parts cement to 5 parts sand; it is of excellent quality. The sewers when built of hydraulic lime receive an increase in the thickness of arch and sides of ⅓. Below subsoil water, however, cement must be used in every case. All work is given out by contract. Sewers of fixed dimensions are paid for by the running meter, and unforeseen quantities are paid for according to itemized prices attached to specifications. The siphon at the Pont de l'Alma consists of two wrought-iron tubes 1 meter diameter, ¾ inch thick, butt-jointed, with rivet-heads on inside, and countersunk to present an even surface. The tubes are 2 feet 6 inches apart, and are entirely bedded in concrete 1 to 3 feet in thickness all around; above low-water they are surrounded by mason-work. The concrete was put in place between sheet-piles, which still form its sides, with riprap on the outside. The walls of street inlets and other appurtenances are also built of *meulière* bowlders, plastered to a smooth surface. Over the extrados of sewers the earth filling is generally 40 inches; in exceptional cases it is 20 inches in streets, and 5 inches on the sidewalks.

### 10. *Statistics.*

| | | |
|---|---|---|
| Area drained by main sewers | acres.. | 15,939 |
| Length of sewers in 1880: | | |
| Main and intercepting (collecteurs) | miles.. | 45 |
| Branch (ordinaires) | miles.. | 348 |
| Total | miles.. | 393 |
| Number of gullies | | 7,877 |
| Length of gully connections | miles.. | 25½ |
| Number of man-holes | | 10,692 |
| Length of man-hole side entrances | miles.. | 14½ |
| Length of house connections | miles.. | 87 |
| Usual length of branches to gullies or man-holes | feet.. | 8 to 9 |
| Length of sewers necessary to complete the system | miles.. | 261 |
| The least grade of street gutters is | | 0.005 |
| Main collectors: | | |
| Collecteur d'Asnières (Type No. 1): | | |
| Length | feet.. | 30,060 |
| Area drained | square miles.. | 9.85 |
| Collecteur de la Bièvre (Type No. 3): | | |
| Length north | yards.. | 5,096 |
| Length south | yards.. | 6,015 |
| Area drained north | square miles.. | 8.69 |
| Area drained south | square miles.. | 1.74 |
| Collecteur du Nord (Type No. 5): | | |
| Length | yards.. | 12,861 |
| Area drained | square miles.. | 4.63 |
| Length of streets having double line of sewers | miles.. | 60 |

Estimate of daily amount of sewage discharged:

| | | |
|---|---|---|
| At Clichy | cubic yards.. | 286,000 |
| Collecteur du Nord | cubic yards.. | 57,500 |
| Total | cubic yards.. | 343,500 |

Temperature (F.) of sewage, Seine, and atmosphere compared in 1876 :

| | *Sewage.* | *Seine.* |
|---|---|---|
| Maximum | 72°.5 | 77°.0 |
| Minimum | 36°.5 | 33°.0 |

Maximum discharge at Clichy is at 11 a. m.; minimum, at 1 a. m.
Maximum discharge at St. Denis is at 9 a. m.; minimum, at 11 p. m.

### III. IN HOUSES.

Various methods of removal are practiced. A large number of houses have tight cess-pools, from which the contents are removed by odorless excavato taken to various establishments for utilization.

Another method is to collect the night-soil in movable casks (*fosses mobiles*), receive solids and fluids as well, and which are exchanged at intervals varyin a few days to a few weeks. Their contents are taken to the same establishme

A third method, the one which at present receives the indorsement of the c thorities, is to receive the night-soil into movable casks which permit the liq drain off (*appareils diviseurs* or *tinettes filtres*) and run into the sewers or cess The retained solids therefore need a much less frequent removal (average 24 t year), and are finally disposed of as before. The casks stand generally in the branches or passage-ways accessible from the sewers, or, where none have been in vaults. The soil-pipe leading down to them is usually of iron, sometimes of cotta pipe 7 inches in diameter. The other end is carried beyond the roof. The or rain water is led down by another pipe (iron or terra-cotta) not passing tl the cask, but running into a terra-cotta pipe 8 inches diameter, along the bot the house branch to the sewer, with a grade of 1:33, and has a basin or runnin (*cuvette*) at the point of its discharge into the sewer. On its way there are nu branches (about 10 feet apart) for inserting cleaning tools. The soil-pipe tern in the casks, from which the liquids run into the horizontal branch just ment A trap is placed in the waste-water pipe before it enters the horizontal pipe. tilating pipe, not less than 8 inches diameter, is carried from the arch of the branch to a point not near any window, but generally above the roof. The *tinette* are made of galvanized sheet-iron of a cylindrical form, are 16 inches in diame from 26 inches to 29 inches in height. A sheet-iron plate, perforated with hol sliding in and out of grooves adapted to the inner side of the *tinette*, divides it cally into two unequal compartments, the combined liquid and solid excreta into the larger one. The use of water-closets is becoming more general.

Number of cess-pools, holding each about 4 cubic yards........................
Number of movable receptacles—
    Retaining both solids and fluids.........................................
    Filtering liquids into sewers..............................................
    Filtering liquids into old cess-pools.....................................

-
1

Number of houses connected with sewer by a passage-way or branch......
    By pipes.........................................................
Number of houses having night-soil service..............................
Daily amount of sewage discharged, cubic feet........................... 9,2
Daily amount of night-soil removed, cubic yards.........................
    Amount from tinettes alone, cubic yards...............................

Since 1852 it is obligatory to build passage-ways from the houses to the sewer ing from 7 feet 6 inches by 4 feet 3 inches to 3 feet 3 inches by 2 feet. At pres feasibility is discussed of using pipes 10 inches to 16 inches diameter. Sinc June 23, the "tinettes filtres" are obligatory for all new houses built on s streets. Since July 2, 1879, it is lawful for small houses to be connected wi sewers by iron or vitrified pipes 12 inches diameter with a least slope of .075, in streets where travel is great and where the subsoil is soft and uncertain haust-steam is not allowed to be discharged into the sewers.

### IV. DISPOSAL OF SEWAGE.

The night-soil removed from cess-pools and in movable casks is disposed of a ous points around the city, the most important being the municipal works at ] lette, where three-fifths of the total quantity is taken. Here the casks are upon canal-boats and towed to Bondy. The night-soil from cess-pools is deliv large casks upon wheels, into which it is pumped at the houses. The conter dumped into an extensive underground reservoir 108 feet by 105 feet by 13 feet deep, and the liquids, which are about six sevenths of the mass, including suspended particles, are pumped by a 25 horse-power engine into two iron conduits, 8 inches diameter each, and 10,500 yards long, to Bondy. The deposited solids are then loaded into casks and taken there by boat. The establishment of La Villette is well kept, the cellars are washed daily, and are well ventilated. At Bondy the contents of the casks are dumped into basins and allowed to dry. The liquids pumped are also allowed to precipitate any solids, the residue in both cases being manufactured into poudrette. The liquids are distilled, and by the aid of heat and the addition of lime-water the ammonia is disengaged and is converted into sulphate of ammonia. The yield varies from 13 to 20 pounds per cubic yard of liquid. The waste waters are dark brown, and are discharged into a sewer leading to the Collecteur du Nord at St. Denis. About 885 cubic yards of night-soil are daily taken to these various dépotoirs.

The sewage proper of Paris is delivered at three points along the right bank of the Seine, at St. Denis, and St. Ouen, where, at the latter place, it has an elevation sufficient to cross the river on a bridge and flow to irrigation farms on the plains of Gennevilliers. At Clichy, it requires pumping and is raised under a head of 30 feet, crosses the river on a bridge to Asnières, and thence flows to the fields. About 60,000 cubic yards in summer and about 40,000 cubic yards in winter are now pumped daily and utilized. The rest flows into the Seine, which is strongly polluted as far down as Epinay. About 120,000 cubic yards of silt, supposed to be deposited from sewage, are yearly dredged. The sewage is led along roads and paths over the flat and sandy surface of the Gennevilliers district in channels, partially under pressure and partially open. The former are built of concrete, and have valves on the surface from which the sewage can be drawn. The district, except a small portion where the experiments on part of the department are made, consists of private tracts, and the owners are at liberty to use the sewage as they desire, or not at all. The ground is quite sandy and gravelly and covered with a sterile soil. With the aid of the sewage it has increased in value so much that the annual rental of land under irrigation increased in the last five years from $17.28 to $36.00 per acre. The sewage is applied either as broad irrigation (en colmatage) or in furrows (en rigoles) between long narrow beds 3 feet in width. The latter is preferred. The position of the beds is changed every year, so that they are placed on the furrow of the previous year. The extension of the sewage carriers over the entire peninsula is gradually to be accomplished.

| | Acres. |
|---|---|
| Irrigated surface in 1882 | 126 |
| Irrigated surface in 1875 | 346 |
| Irrigated surface in 1878 | 914 |
| Irrigated surface in 1880 | 1,020 |
| Area available | 12,000 |

or one acre for 170 to 200 persons.

No ill effects have been caused by the irrigation works. Since they were started, a new village, Gresillons, has sprung up in the midst of the territory, with a death-rate averaging only from 19.5 to 25.3. Irrigation was begun in 1869. It is intended in future to purify the sewage more by filtration through the soil than by irrigation alone. The two methods will be combined, however, as much as possible.

## D.—MAINTENANCE OF SEWERAGE WORKS.

### 1. *Appliances.*

*a. For removing night-soil.*—Cess-pools are cleaned by pumping the contents into cylindrical iron carts with a capacity of from 70 to 140 cubic feet. These, when full, are hermetically sealed and conveyed to the several depots, La Villette, &c., for disposal. The common "fosses mobiles" are strong wooden casks containing from 4 to 6 cubic feet. They are closed with a tight-fitting cover and taken to the depots in carts for disposal. The "tinettes filtres" are made of galvanized sheet-iron of a cylindrical form, 16 inches diameter and 26 to 29 inches in height, with a movable screen to separate the fluids from the solids. They are connected by a movable bayonet-joint with the soil-pipe, and by a small movable India rubber pipe with the branch from the sewer. They can thus be readily removed, and after being tightly closed are rolled under a manhole, hauled up, placed upon a cart and taken to the depots for disposal.

*b. For cleaning sewers.*—The appliances are as follows:

The "bateau-vanne" is a boat with a movable apron or scraper (vanne) of the shape of the invert, but an inch or two smaller, perforated with three small openings and suspended at the bow so that it can be raised or lowered. When it is lowered to within a small distance of the bottom the water rises behind it, and, besides propelling the boat, rushes with great velocity through the narrow opening and stirs up the sediment. This sediment as it accumulates in front of the apron is pushed forward by it through the rising head of water and thus brought to the outlet. It is used in types Nos. 1 and 3.

The "wagon à bascule," or tip-wagon, is a truck, into which the silt is thrown and carried to the outlet. The "wagon-vanne" is a truck running on rails about 4 feet apart, fastened to the edge of the "piedroit" (path). It operates exactly like the boat, in having a movable apron in front, by which the detritus is pushed down the sewer. It is used on the sewers of types Nos. 2, 4, 5, 6, 7, and 8.

The "wagons ordinaires" are simple trucks for the sewers of an oval shape without banquettes, or types Nos. 10 to 18. The scrapers and shovels are used in the latter to loosen the deposit and load it into the trucks or push it forward into larger sewers. The scrapers are similar to the common hoe, with its edge fitting the curve of the invert. Brooms are used to clean the banquettes and side entrances. The sewers of types 10 to 18 are sometimes flushed by pen-stocks or timber sluice-gates, hinged at the side and worked from the top of a sewer through a manhole. The siphon crossing under the Seine at the Pont de l'Alma is cleaned by means of a ball of hard wood 53¼ inches diameter, 5.9 inches less than diameter of pipe, and weighing 187 pounds, which is passed through it at intervals, generally once a week. It is pushed along by the force of the water, and by being lighter it rolls along the soffit which increases the velocity of water along the bottom and causes the sediment to be scoured up and moved toward the outlet.

At certain places there are recesses in the sewers for collecting the silt, which is then removed by the trucks ("wagon à biscule").

### 2. *Method.*

*a. Of removing night-soil.*—As stated under 1, the night-soil is collected in movable casks or pumped from cess-pools and taken to La Villette or other dépotoirs, where their contents are either removed from the city finally or made into poudrette. The exchange of the casks is very regular and at brief intervals, many arriving at the dépotoirs not more than half filled. They are all well cleaned before being replaced. There is comparatively great cleanliness in the entire operation.

*b. For cleaning sewers.*—The sewers having banquettes (Nos. 1 to 9) are cleaned mechanically by the flushing apron or scraper; the rest are cleaned by hand, the mud being either removed into a large sewer with trucks or boats, or out of man-holes into the streets and loaded into carts. The water in the former case passes through the space between the scraper and the sides of the sewer, as well as through the small apertures in it, and creates so violent an agitation in front that all the solid matter is held in suspension and driven forward with the scraper itself. It sometimes happens that one passage of the boat or truck is not sufficient to remove all the silt, and a second one is necessary. When the flow is too slight to float the boat, the water is temporarily raised by dam-boards exactly fitting the invert. The boats and trucks are attended by three men working the apron or assisting the motion of the boat. About 2,500 feet can so be gone over in a day. The sewers are rarely cleaned before the mud is several inches deep. The motion of the flushing boats and trucks is hardly 1 to 2 inches per second.

Acids must be neutralized before being discharged into the sewers. Steam or fluids of a temperature greater than 86° Fahrenheit are not admitted into sewers.

The siphon at the Pont de l'Alma is cleaned by passing the ball. It has been in use many years and given no trouble nor reason to anticipate any. There is a difference of level between the two ends of 1 foot 8 inches, and this difference can be increased to nearly 7 feet by damming up the water at the southern end. A great velocity for simple flushing and for passing the ball is thus obtained. After the ball is inserted at one end it requires generally but a few minutes to appear at the other, pushing the silt in front of it. With a head of 1 foot 8 inches its velocity is about 3 feet per second.

The flushing and cleaning is executed in ordinary times by 550 to 600 men, under the supervision of 22 "piquers," 25 overseers, 5 sub and 1 chief "controleur." The city cleans 21,500 out of the 23,600 house-connections.

The condition of the sewers is generally clean, and no strong, disagreeable odor prevails, except in the sewer which brings the foul waters from the Bondy establishment. During the summer months visitors are weekly taken through the large collectors in a cleaning-boat.

## E.—COST OF SEWERAGE WORKS.

### 1. *Management and maintenance.*

Department for sewerage in 1879:

| | |
|---|---|
| Corps for design and construction | $193,936 |
| Materials and labor (exclusive of new work) | 973,900 |

| | |
|---|---|
| rsons for inspection of cleaning sewers and night-soil service | $71,000 |
| nsion and repairs to city sewerage | 420,000 |
| truction of house branches | 28,000 |
| Maintenance of sewers: | |
| ic sewers, flushing, &c | 243,200 |
| e branches (reimbursed to city) | 76,000 |
| ic buildings, including night-soil removal | 45,400 |
| ging sludge from river | 36,000 |
| llaneous | 20,400 |
| | 421,000 |
| ation of sewage at Gennevilliers | 78,000 |

Department for water supply in 1879:

l expense, 5,860,280 francs=$1,172,056.
al cost of cleaning sewers per head of total population, 12.5 cents.
al cost of pumping sewage per head of total population, 4.5 cents, or about one ntime for one cubic meter pumped.
al cost of night-soil service per head of population, 55 cents, or $1.23 per cubic rd.
al cost of pumping night-soil to Bondy, 2.92 cents per cubic yard.
al cost of transporting casks to Bondy, 7.32 cents per cubic yard.

il-pipes in houses supplied with the filtering casks are taxed with $6 annually. removal and exchange of one cask is charged to owners with 30 cents. There is verage of 6.3 exchanges per annum. Therefore annual cost is about $1.90. Protors pay for the construction of house branches. Cost of the sewage purification ks from 1869 to 1880 was about $600,000. Cost of maintenance and studies up to was about $600,000.

| | | |
|---|---|---|
| t of ground before sewage irrigation (1868) | per acre | $12 15 |
| t of ground after irrigation: | | |
| 1872 | per acre | 12 80 |
| 1875 | per acre | 17 28 |
| 1877 | per acre | 24 00 |
| 1880 | per acre | 36 00 |

### 2. *Construction.*

timated cost of existing sewers is $20,000,000, including 355 miles of main and ch sewers and 123 miles of house branches.
timated cost to complete the system is $8,911,100.

Present contract prices of the different types, &c. (see C. II. 1), are:

| | Francs per meter. | Per foot. |
|---|---|---|
| **Sewers, for** | | |
| No. 3 | 367.42 | $22 40 |
| No. 5 | 299.67 | 18 00 |
| No. 6 | 241.93 | 14 75 |
| No. 6, bis | 258.82 | 15 80 |
| No. 8 | 172.97 | 10 65 |
| No. 9 | 149.02 | 9 08 |
| No. 10 | 112.52 | 6 86 |
| No. 12 | 97.11 | 5 92 |
| No. 13 | 92.06 | 5 61 |
| No. 13, bis | 81.62 | 4 98 |
| No. 14 | 77.45 | 4 72 |
| **House branches, for** | | |
| Type No. 1 | | 4 47 |
| Type No. 2 | | 3 43 |
| Type No. 3 | | 3 13 |
| Type No. 4 | | 2 82 |
| **Man-holes, for** | | |
| Horizontal branch, 2 meters high | | 5 11 |
| Shaft, square section | | 2 80 |

*d.* **Street-inlets**, for

| | |
|---|---|
| Horizontal branch, 0.80 to 2 meters high | |
| Shaft, rectangular section | |

All prices under *a*, *b*, *c*, and *d* are for paved streets, for meulière masonry ment mortar.

Cost of underground sewage carriers at Gennevilliers (concrete) is about per running foot, excluding cost of excavation. Flushers are paid 60 cents to day. Foremen have salaries of $400 to $625 per year.

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## BERLIN.

### A.—STATISTICS OF LOCALITY.

#### 1. *Population.*

1840—300,000; 1860—600,000; 1880—1,118,630.

#### 2. *Area.*

| | |
|---|---|
| Municipal | 1 |
| Area of lowland | |
| Area of highland | |
| Area built up | |

#### 3. *Dwellings.*

| | |
|---|---|
| Number of houses, about | 2 |
| Number of dwellings to one house | |
| Average number inhabitants per dwelling | |
| Average number inhabitants per house | |

#### 4. *Water supply.*

Pumped from River Spree, 31.7 gallons per head per day.

#### 5. *Mortality.*

Average for a number of years, 30.6. There has been a gradual decrease from when it was 32.6, to 1879, when it was 27.7—the lowest rate since 1867.

#### 6. *Meteorological.*

| | Fahre |
|---|---|
| Temperature, mean annual | |
| Highest monthly mean temperature, July, 1865 | |
| Lowest monthly means since 1740: | |
| January, 1838 | |
| January, 1848 | |
| January, 1823 | |
| Lowest daily mean, 1850, January 22 | – |
| Highest daily mean, 1865, July 20 | |
| Highest 5-day mean, 1868, August | |
| Lowest 5-day mean, 1861, January | |
| Warmest observed temperature, July, 1819 | |
| Coldest observed temperature, January, 1823 | — |
| Mean of January for 150 years is | |

Rain.—Annual mean, 22.32 inches; number of rainy days per annum, averag several years, 118.

Maximum storms July 11, 1858, 2.56 inches fell in 14 hours =.003 inches per mi .80 inches fell in 20 minutes =.040 per minute.

Prevailing winds, west (decided).

Frost penetrates ground from 40 to 50 inches.

### 7. *Topographical.*

iate on both banks of the Spree, a small river rising in Central Germany, and miles from its confluence with the Havel River. The largest part of the town ı a sandy plain, varying in elevation only from about 15 to 18 feet above low ·. In the southwest part of the city there are areas varying 10 to 15 feet above 'ater. The ground gradually rises as its distance from the river increases, espe- towards the north, where it reaches +25 feet near the old boundary. It rises ıigher at a few points both north and south. In the south there is a sudden tion of +111 feet, called the Kreuzberg. Low water in the Spree is about 95 bove mean tide in the Baltic. The discharge of the Spree, which averages from 200 feet in width, is at—

| | Cubic feet per second. |
|---|---|
| ary low water | 1,000 |
| me low water | 506 |
| ary high water | 2,000 |
| me high water | 4,808 |

river runs through the city in several arms.

### 8. *Physical.*

city is closely built up in the central and eastern section. The western con- the parks and villa-residences. The streets are comparatively wide, and are y paved with stone blocks. Recently asphalt is being much used.

### 9. *Geological.*

the older city and lowland the surface to a depth of five feet is of recent forma- either dug over or filled in. Below is alluvial sand from eleven to forty feet , and below this is diluvial loam and coarse gravel, rising to the subsoil water- at a few places in the lower city. Near the river there are occasional beds of and of infusorial earth in depths of eight to twenty-six feet. For building pur- these "pockets" have proved very troublesome. Toward the higher grounds iluvium rises to the surface.

## B.—MANAGEMENT OF PUBLIC WORKS.

ch department is headed by a "Baurath" (chief engineer), responsible to the cipal council. The design and construction of the new sewerage works are un- special and temporary department. For the latter there is a central office for shing principal designs and deciding general questions. It is headed by a di- r and six assistants. Other matters and the execution of the works are in charge vision engineers, one for each main drainage area (radial system), who have a corps of several assistants, according to amount of work. The works are di- y superintended by an inspector and "conductors." Maintenance of sewers is systematic. So far only Radial System III is finished. The pumping station ges 16 persons, the maintenance of the sewers of the district, 14 persons. The ation works are also in charge of the temporary sewer department, under 1 in- or, with 1 assistant and 40 sewage distributors.

## C.—DESIGN AND CONSTRUCTION OF SEWERAGE WORKS.

### I. GENERAL SYSTEM AND ALIGNMENT.

mbined water-carriage and disposal on sewage farms. As all sewage requires ing, and as the surface of the city is extremely flat and low, it is divided into dependent artificial drainage areas or districts to obtain better gradients and epth of sewers. Each one is called a "radial system," and they are numbered I to XII. The city proper is covered by five, I to V; the rest are peripheral. sewage from each district is collected at a lowest point, the pumping station, rom here raised through iron mains to either of two farms, one situated to the east, the other to the south of Berlin. The stations are situated at or near the or one of its branches, and the sewers radiate from it over the district. At pres- ly Radial System III is finished, I and II are nearly so, and others have been enced. The pumps are intended to raise, besides the sewage, only a first flush n-water; therefore numerous overflows are provided to relieve the pumps of any r quantity. On broad streets, over 60 feet in width, a sewer has been laid on each side. All sewers are as much as possible connected with each other, and temporarily separated only by valves, in order to avoid dead ends, to flush lower from higher mains (Lindley principle), and to permit the sewage to flow into other sewers in case of stoppage in any one. All pipe sewers are laid in straight lines between man-holes (Rawlinson principle). In general the sewers are divided into collectors, which are deep and built of brick; into pipe sewers for the branches and higher districts, and into storm-water overflows, for which partially old sewers were made use of. The present plan was adopted in 1873, after an inquiry of a commission appointed in 1867. The system is designed by Mr. Hobrecht.

### II. IN STREETS, ETC.

### 1. *Shape and size of sewers.*

Circular pipe sewers are used up to 20 inches diameter. Brick sewers are egg-shaped, except some of the larger ones, which are circular or flat elliptical, for want of sufficient height under street. The width of the egg-shaped section is two-thirds its height. The pumping mains are of iron and 1 meter diameter each, except one, which is only three-quarters of a meter in diameter. The size of the sewers is determined by Eytelwein's formula, in the following form, for meters:

Circular sewers, running full, $v=50\sqrt{\frac{r}{2}s}$

$$\text{Log. D}=2.0456+\frac{5\ \text{log.}\ r+\text{log.}\ s}{2}$$

Egg-shaped sewers, running full, $v=50\sqrt{\frac{4.594}{7.93}rs}$

$$\text{Log. D}=2.2426+\frac{5\ \text{log.}\ r+\text{log.}\ s}{2}$$

Egg-shaped sewer, ⅔ full, $v=50\sqrt{\frac{3.023}{4.788}rs}$

$$\text{Log. D}=2.0803+\frac{5\ \text{log.}\ r+\text{log.}\ s}{2}$$

In which $v$ equals velocity in meters per second; $r$ is the mean radius; $s$ the sine of the slope, and D the discharge in cubic meters per second. The quantity of rainfall used for calculation is ⅞ inches per hour, of which ⅓ is assumed to evaporate, ⅓ to penetrate the ground, and the remaining ⅓ (7 millimeters per hour) to enter the sewers.

The quantity of sewage estimated is 130 liters (30 gallons) per day per inhabitant, of which one-half runs off in 9 hours, and for 800 inhabitants per hectare (324 persons per acre). At present there are only half this number. The minimum size for pipe sewers is 8 inches; maximum, 20 inches. The brick sewers are classified into eleven types, varying from one meter to two meters in height.

### 2. *Depth and grades.*

The depth of cellars was regulated by the subsoil water, which stands at +1 meter above mean water near the river, and at +2.2 meters at the upper end of the lower city. Cellars must be 1 foot above subsoil-water level. Depth of pipe sewers varies from 1 meter to 4 meters below surface, and of brick sewers, which are laid deeper to act as collectors, from 2 meters to 5 meters. The latter are often below subsoil water, and are made water-tight with great care. The grades are, as a rule, very light, on account of the flatness of the country; yet light grades are even preferred in some instances to obtain a greater bulk of water for flushing. The deposits observed in Berlin seem, however, to be greater than elsewhere. The minimum grades used are for—

| | |
|---|---|
| Sewers that can be walked through | 1 : 3000 |
| Sewers that can be crawled through | 1 : 1800 |
| Pipe sewers | 1 : 800 |

Pipe sewers frequently have a drop in the man-holes.

### 3. *Junctions, connections, overflows, outfalls.*

The junctions of large sewers are generally made at right angles, except where streets join at acute angles. They are usually in rectangular chambers, with a cylindrical arch, and in a few of which there is a tongue. Funnel arches are avoided.

When curves are made to enter the chamber they mostly have a very short radius. No allowance is made for loss of head in the curves. House connections are made at an angle, and are inserted where necessary when sewers are built. Overflows, of which there are a great number besides those at the pumping stations, are arranged so that they can be adjusted, with regard to the height of water in the river, by iron bars of square section (2 inches by two inches), which are placed loosely on each other across the opening and form a dam, which, therefore, can be raised and lowered any distance at pleasure. These dams are used to prevent the ingress of river water during its high stages. The overflows at the pumping stations have acted fourteen times in a year, with an average duration of 2 hours and twenty minutes each time. There are two ultimate outfalls for the sewage, one on the Osdorf farm, the other at the Falkenberg farm. At present much of the sewage still flows into the Spree.

### 4. *Ventilation.*

The ventilation of sewers is achieved by perforated man-hole covers in the middle of the street, by the street gully inlets, and by the soil pipes of the houses. No objectionable odor has been noticed to arise into the street, and the air in the sewers themselves has but a slight smell. The odor at the pumping stations, which are located at various points within the town, is remarkably slight when at all noticeable.

### 5. *Man and lamp holes, flushing shafts.*

The man-holes are generally situated directly over the sewer and are covered by a circular cast-iron grating, open near the periphery and containing blocks of wood in the middle for deadening noise. One inch or two below the cover is a sheet-iron plate to catch street dirt, with holes for ventilation in the middle. The man-holes are descended by cast-iron steps set into the wall. For brick sewers the upper diameter is 21 inches, and retaining this width in the direction of the sewer, they increase in width across the sewer and generally rest on the side walls. For pipe sewers the man-holes increase in diameter from 21 inches to 3 feet 1 inch at 4 feet below the surface, which latter diameter they maintain to the bottom. For pipe sewers the bottoms are flat and a few inches lower than the outlet pipe, the inlet pipes being usually higher than the outlet. There are no special lamp-holes and flushing shafts. Man-holes are placed at all street crossings and changes of directions; otherwise they are from 200 to 300 feet apart.

### 6. *Gullies.*

The gullies have a horizontal inlet in the gutters, the grating being 15¾ inches by 19¾ inches. They have a catch-basin 26 inches square and 34 inches deep below the outlet. The entire depth of the gulley is 7 feet 4 inches below the gutter. The outlet is rectangular, 4 inches high and 8 inches wide through the wall of the basin, then it is circular, 6½ inches in diameter to the sewer. The trap, or rather screen, as it is perforated with two holes at the top, each an inch in diameter, is a sheet-iron flap, hinged above the outlet so that it can be raised in case of obstructions. It stands 2½ inches from the wall, but is bent to fit closely against it with its sides. It is mainly for the purpose of preventing floating matter from getting into the sewer. Gullies are never placed at intersections or near crossings, but in the block.

### 7. *Pumping stations.*

There is to be a pumping station for each radial system. It is intended to pump, besides all sewage, an amount of rain-water of equal quantity. The following notes refer to system III, as it is the only one entirely finished. The rest will be in similar proportions. The station contains buildings for engines, boilers, coal, employés, &c., a well for water of condensation, a large circular catch-basin, with screen and an overflow to river. There are 6 engines (Woolf's horizontal), 2 coupled to one fly-wheel, with a total of 360 horse-power, driving 6 pumps, with a capacity of 1,000 cubic feet per minute. Only three of the pumps are ordinarily in use, the other three being kept for rainy weather. In 1878 4,839,400 cubic meters were pumped to Osdorf, requiring 25,500 hectoliters coal at a cost of 33,500 marks (1,278,280,000 gallons, with 3,330 cubic yards coal, costing $8,400). All of the pumps south of the river amount to 500 horse-power. The stations are very neat, located in the city, and are without any noticeable odor. The lift to the southern farm, Osdorf, is 75 feet; to the northern farm, Falkenberg, 105 feet.

### 8. *Miscellaneous.*

For crossing the canals there are four pipe bridges and one inverted syphon.

### 9. *Materials and construction.*

Materials used for sewers are pressed brick and terra-cotta pipe. The ordinary sewers are all pipe; the main collectors are brick. The subsoil being very sandy, and sometimes peat and bog, there were great difficulties to encounter, as many sewers were built below subsoil water, which should of course not be pumped. A water-tight cradle was usually built into the trench by means of concrete, molded under the water and reaching up to its surface. After hardening, the trench was pumped dry. The sandy soil above the water required sheet-piling in most places. The invert of brick sewers was generally made either of terra-cotta blocks or lately of blocks formed of bricks, about a yard long and 18 inches wide, which were lowered into the trench. A course of smooth stretchers was laid on top of the blocks in both cases. The brick-work is made water-tight with the greatest care, because all of the ordinary flow of sewage must be pumped. Wedge-shaped bricks are used for arches of four patterns, for diameters from 1 meter to 2 meters. Bricks molded to circular curves, both headers and stretchers, are used for man-holes. Size of ordinary bricks is 9¾ inches by 4½ inches by 2⅝ inches. Pipe sewers are also laid with greatest care, from the lowest point upwards. To control an accurate gradient and alignment a lamp is kept burning at the starting point, which by reflection shows any irregularity and enables the pipe to be thoroughly cleaned. The pipes are jointed with gasket and puddled blue clay on the outside, and cement from the inside if the pipe is large enough. This jointing has given perfect satisfaction. One mason and four helpers can lay 70 feet a day of the larger and 100 feet of the smaller sewers. The mortar is mixed of German Portland (Stettin) in proportion of 1:3 of sharp sand. Concrete is made of 1 part cement, 3 of sand, 5 of stone. The joints are small and carefully struck so that the inner surface is very smooth. The hinged flap in the gullies is of sheet-iron, the outlet pipe through the brickwork including the downward turn is made of cast-iron. The gullies and man-holes are usually built on a large flag-stone as a foundation. The foundations for sewers are usually concrete, from 1 foot to 2 feet 6 inches deep. The execution of the work is entirely by day's labor, under the direction and inspection of the city officers, except the excavation and sheet piling, which are done by contract. All materials are obtained from the best makers, not necessarily from the lowest bidders.

### 10. *Statistics.*

| Radial system. | Area, acres. | Inhabitants, about— | Houses. | Inhabitants per house. | Inhabitants per acre. |
|---|---|---|---|---|---|
| I | 670 | 103,000 | 1,190 | 87 | 153 |
| II | 862 | 167,000 | 2,860 | 58 | 193 |
| III | 964 | 107,000 | 2,860 | 37 | 116 |
| IV | 2,130 | 244,000 | 4,080 | 60 | 113 |
| V | 1,819 | 194,000 | 2,830 | 69 | 106 |
| VI | 1,001 | 46,000 | 720 | 64 | 46 |
| VII | 642 | 36,000 | 770 | 47 | 56 |
| VIII | 1,413 | 20,000 | 300 | 67 | 14 |
| IX | 1,258 | 11,000 | 240 | 46 | 9 |
| X | 971 | 35,000 | 550 | 64 | 36 |
| XI | 828 | 6,000 | 110 | 55 | 7 |
| XII | 430 | 8,000 | 120 | 67 | 18 |

Length of sewers finished December, 1880:

| | Miles. |
|---|---|
| Pipe | 113 |
| Brick | 13 |

Dwellings (not houses) connected, 30,000.

Length of brick sewers built daily in season, about 450 feet.

Distance from pumps to southern sewage farm, 8 miles.

Lift of pumps, 70 feet.

Sewage reaches farm from extreme dwellings in 5 hours.

Greatest calculated dilution of sewage at the moment when overflows begin to act, 1 to 8.186.

*Greatest* dilution when sewers are running full, 1 to 153.2.

*Statistics of Radial System III (finished).*

| | Yards. |
|---|---|
| Length of brick sewers 3 feet to 6 feet 6 inches high | 10,267 |
| Length of pipe sewers | 73,861 |
| Length of storm-water overflows (brick) | 1,969 |
| Length of storm-water overflows (pipe) | 656 |
| Number of gullies | 1,450 |
| Number of man-holes | 1,060 |
| Number of storm-water overflow sewers | 5 |
| Number of short overflows | 30 |
| Water consumption per head ........ gallons | 33½ |
| Houses (not dwellings) connected | 2,445 |
| Average number of dwellings to 1 house | 8.7 |

Sewers are built for a density of population of 800 per hectare, or 320 per acre.

*Statistics for other systems, in* 1880:

| | |
|---|---|
| Length of brick sewers finished ........ yards | 56,869 |
| Length of pipe sewers finished ........ yards | 53,730 |
| Length of storm-water sewers finished ........ yards | 5,877 |
| Number of houses connected | 1,200 |

### III. IN HOUSES.

Sewer connections are obligatory, since 1874, as soon as sewer is laid in front of property. All excrements, waste and rain water must be led into sewer. Cess-pools are prohibited. Owners must submit a plan of a complete house-drainage for examination, and it must be executed within six weeks after approval. The execution is subject to inspection. The city lays the house-pipes to the inside of the front wall, and the rest is done by the owner. Where sewers cannot yet be built, the cask system is obligatory in the mean time. The use of the public water supply is obligatory wherever there are pipes in the street. All old works, including cess-pools which have been superseded by the new ones, must be removed within thirty days' notice. Soil-pipes 4 inches in diameter must be carried beyond roof or into chimneys. Every inlet is to have a fixed strainer. Below every inlet there must be a water-trap. The outlet from water-closet (neck) shall not be over 2½ inches in diameter. Water-closets must have ample flushing arrangements. The main house-drain (maximum 6 inches in diameter) after entering the house is to be provided with a valve to prevent back flow from the sewer, with a removable lid.

Condensation water is only allowed to enter sewers on special permission, exhaust steam never. After house drainage is completed, the old gutters are filled, and granite curbs, 12 inches broad and 10 inches deep, set on concrete, are built in their place. Sink-pipes must have a diameter not greater than 2 inches. Privies in the yards are to have a hopper closet with a trap below frost. Rain-water from the yards must be led into gullies also trapped below frost, and not run into the street over the sidewalk. The portion of the main pipe leading through the wall and into the house is of cast iron and asphalted—the soil-pipe likewise, and both have leaded joints. Exceptionally, vitrified pipes are permitted under the cellars. Cellars must be 1 foot above the highest subsoil-water level.

Yard gullies are built of brick, well cemented, 15 inches square and 5 feet deep, and the outlet must be 3 feet 4 inches below surface. It must be trapped. Grease traps are to be inserted wherever necessary. They are to be of cast iron, enameled, 10 inches by 14 inches, and at least 14 inches deep. The minimum fall for house-pipes is 1.25 per 100; the maximum for horizontal pipes is 3 per 100. The tax for house connections is not a fixed one, but proportional to the supposed advantages gained, and is adjusted every year according to the amount of money required to extend the works. In 1879 it was about $45 per building in the districts where works were being executed.

### IV. DISPOSAL OF SEWAGE.

All of the sewage is to be pumped and distributed over two farms for irrigation and filtration, one to the northeast, for the part of the city north of the Spree; the other to the south, for the southern portion. The former is at Falkenberg, 6 miles from the center of Berlin, with an elevation of 102 feet above the Spree, and an area of 1,830 acres; the latter is at Osdorf, 9 miles from the center of Berlin, with an elevation of 72 feet above the Spree, and an area of 2,050 acres. The level portions are used for filtration and winter storage, the gently sloping areas for the furrow system, and greater slopes for broad irrigation. A novel feature are the winter basins into which the sewage is turned, after vegetation ceases, to a depth of 2 feet, and allowed to soak away. The odor from them is very great, but no houses are within a mile.

In the spring the ground is plowed, and summer grain of excellent quality grown upon it. The entire farm is to be subdrained. The effluent is satisfactory. The soil consists of a loamy and almost pure sand, and its fertility before sewage is turned upon it is very poor. Now, crops are raised better than the average quality of the ordinary farm. The Falkenberg farm is not yet prepared. Osdorf receives the sewage from Radial Systems I, II, and III through two mains 1 meter in diameter each. The farm is divided into fields, meadows, vegetable gardens, and winter basins which are fields in summer. The gardens are leveled and every meter has a furrow into which the sewage is turned. The sewage is delivered at the two highest points into stand-pipes, its height being indicated by means of a float and flag. From these points pipes are laid in various directions along the ridges, from which the sewage is turned into open carriers 20 inches deep, and led to the different fields. About 1,000 acres are at present prepared and operated. About 0.27 gallon per second per acre is delivered to the farm. The temperature of sewage arriving at farm is seldom less than 41° Fahr.

| | Temperature of— | | Minimum temperature of air during month. |
|---|---|---|---|
| | Sewage at farm. | Air. | |
| December, 1870 | +40.5 | +25.5 | +1.40 |
| January, 1871 | +36.1 | +23.0 | —5.35 |
| February, 1871 | +35.4 | +29.8 | —4.45 |

The city owns and operates the farms. Irrigation was begun systematically in 1873.

## D.—MAINTENANCE OF SEWERAGE WORKS.

### 1. *Appliances.*

Pen-stocks are not used. The pipe sewers are flushed by having wooden plugs inserted and drawn when sufficient water has accumulated, or by using flaps for the same purpose. The cleaning gangs take with them, in a small wagon, a bundle of iron rods 8 feet long and ½ inch diameter to insert into the pipes, buckets, a tripod, two pieces of hose to attach to water plugs, a water meter to measure the quantity used, lanterns, scrapers of wood, and cylindrical brushes with sufficient quantity of tarred rope to draw them through the pipes. The large brick sewers are cleaned by hand with scrapers and shovels.

### 2. *Method.*

About every two weeks all pipe sewers are flushed, generally with hydrant water. For this purpose the ends of the pipes in a man-hole are closed either by flaps or plugs, the man-hole itself is filled with water by a hose attached to the nearest fire-plug, and the flap of the lower pipe is raised, which allows the water to rush through it with an initial head of 6 to 10 feet. Beginning at the highest point the silt is flushed from section to section until it is discharged into the brick sewers, where the greater quantity of water and the average velocity of 1 foot 8 inches generally remove most of the sediment, and if not, it is swept or pulled by scrapers to a convenient man-hole and there lifted into buckets. The brick sewers are inspected, walked through, and cleaned once in 3 weeks. The large catch-pit at the lower end of each system (pumping station) is cleaned weekly. The sand removed is black and has a very trifling odor. When the flushing of pipe sewers is not sufficient, cylindrical brushes are drawn through them simultaneously with the flushing. From Radial System III about 600 cubic yards of silt were removed, or less than a pint a day for each house, including street silt. On account of the light grades a good deal of silt is therefore deposited. There has been no stoppage as yet necessitating the taking up of any section, although the system has been in operation for four years. To clean the sewers of System III there are three gangs, each consisting of 1 foreman with three men, to whom is allotted a section of about 800 houses and 17 miles. The cleaning in the principal streets is done at night. One gang cleans about 660 feet of pipe in one night, and removes ½ to 2 cubic yards of silt. At the pumping station there is daily removed from the screen about one wheel-barrow full of paper, rags, sticks, &c., which are burnt in the furnaces.

In 1878 there were pumped from System III to the farm 3,505,150 gallons; in 1879, 3,716,604 gallons. In the latter year this quantity has been estimated to consist of 9.1 per cent. rain-water, 1.6 per cent. of water used for flushing, the rest of sewage

**per, being 1,358 gallons per house and 32 gallons per head daily. Storm-water over-ows acted 14 times in the same year, averaging 2 hours and 20 minutes in duration.**

### E.—COST OF SEWERAGE WORKS.

#### 1. *Management and maintenance.*

**neral** office:

| | Marks. |
|---|---|
| Director and 6 persons | 18,472 |
| Office, &c | 8,028 |
| | 26,500 |
| or, | $6,630 |

**adial** System I (not finished):

| | Marks. |
|---|---|
| Pumping, 10 persons | 12,540 |
| Coal (16,750 marks) and miscellaneous | 24,845 |
| Cleaning, 2 inspectors and 6 laborers | 10,064 |
| Clothing, materials, tools, and carting | 8,151 |
| Repairs | 500 |
| | 55,700 |
| | $13,925 |

**adial** System II (not finished):

| | Marks. |
|---|---|
| Pumping, 10 persons | 12,550 |
| Coal (18,875 marks) and miscellaneous | 28,125 |
| Cleaning, 3 inspectors and 7 laborers | 12,902 |
| Clothing, materials, tools, and carting | 10,152 |
| Repairs | 100 |
| | 63,819 |
| | $15,955 |

**adial** System III (finished):

*a. Pumping station.*

| | Marks. | |
|---|---|---|
| 1 engineer, dwelling provided | 2,100 | $525 |
| 5 machinists, dwelling provided for 3 | 7,380 | 1,845 |
| 5 stokers, dwelling provided for 1 | 3,360 | 840 |
| 2 laborers, cleaning engines and building | 1,800 | 450 |
| 1 laborer for grounds, and miscellaneous | 630 | 158 |
| 1 gatekeeper | 1,080 | 270 |
| For intermediate pumping station: | | |
| 1 engineer | 1,620 | 405 |
| 1 machinist | 1,440 | 360 |
| | Marks. | |
| stoker and laborer | 900 | $225 |
| Total | 20,310 | 5,078 |
| Materials: | | |
| 2,645 cubic meters coal, at 13.50 marks | 33,062 | 8,265 |
| Oil, packing, and cleaning materials | 6,690 | 1,673 |
| Brooms, rope, and sundries | 192 | 48 |
| Clothing and boots | 266 | 66 |
| Carriage hire | 108 | 27 |
| Water tax | 1,050 | 263 |
| Gas | 3,500 | 875 |
| State tax | 1,405 | 351 |
| Repairs to engine and buildings | 2,999 | 750 |
| | 49,272 | 12,318 |

*b. Maintenance of sewers.*

| | Marks. | |
|---|---|---|
| 1 inspector, dwelling provided | 3,000 | $ |
| 3 foremen, at 4.50 marks per day | 4,927 | 1, |
| 9 laborers, at 3 marks per day | 9,855 | 2,4 |
| Extra labor | 1,826 | 4 |
| Night-watchman, at 1.50 marks per day | 548 | 1 |
| | 20,156 | 5, |

Materials:

| | | |
|---|---|---|
| Clothing, boots, and grease | 1,120 | |
| 95,000 cubic meters of water for flushing at 15 and 10 pfennigs per meter | 12,967 | 3, |
| 450 loads of silt removed, at 4 marks | 1,800 | 4 |
| Hose, &c | 955 | |
| Repairs, alterations | 7,351 | 1, |
| | 24,193 | 6, |

Radial system IV (not finished):

| | | |
|---|---|---|
| Pumping, 10 persons engaged | 12,850 | 3, |
| Coal (21,375 marks) and miscellaneous | 31,125 | 7, |
| Cleaning, 3 inspectors and 7 laborers | 13,002 | 3, |
| Clothing, tools, materials, and carting | 11,083 | 2, |
| Repairs | 100 | |
| | 68,160 | 17, |

Maintenance and improvements of sewage farm at Osdorf. (Radial Systems I, II, II

| | Marks. | |
|---|---|---|
| 1 inspector | 1,600 | $ |
| 1 assistant inspector | 1,000 | |
| 27 sewage distributers, at 910 marks | 24,570 | 6, |
| 13 assistant sewage distributers, at 600 marks | 7,800 | 1, |
| Farming, inspection, labor, and materials | 97,400 | 24, |
| Insurance, school, police, and taxes | 7,316 | 1, |
| Repairs and alterations to farm and tools | 13,000 | 3, |
| House expenses | 2,000 | |
| Cattle and food | 72,000 | 18, |
| Seeds and planting trees | 19,250 | 4, |
| Miscellaneous | 1,534 | |
| | 247,470 | 61, |

Maintenance and improvements of sewage farm at Falkenberg. (Radial Systems and V, not completed):

| | Marks. | |
|---|---|---|
| Total expenses | 5,650 | $1, |

Receipts from Osdorf farm:

| | | |
|---|---|---|
| Sale of produce | 168,390 | $42, |
| Sale of stock, milk, manure | 78,440 | 19, |
| Miscellaneous | 660 | |
| | 247,490 | 61, |

Miscellaneous:

For Radial System III there were pumped in 1878, per house (not dwelling), 528, gallons, with 1.4 cubic yards of coal for $3.33. Price of coal, $2.38 per cubic yard.

Tax for water used for flushing, 28.4 cents per 1,000 gallons.

Funds for building the new works are raised by a general loan at 4 per cent., w 1 per cent. sinking fund. In addition there is an assessment on properties, bein tax of 1 per cent. of the increased valuation of each property due to the construct of the sewerage works.

### 2. *Construction.*

Total cost of radial systems up to 1880:

| | |
|---|---|
| *I*, Rad. system nearly finished | $1,225, |
| *II*, " " nearly finished | 1,575, |
| *III*, " " finished | 1,52 |
| *IV*, " " nearly finished | 2,40 |
| *V*, " " nearly finished | 2,1 |

aterials:

ost $7 to $10; cement is worth $2.25 per 400 pounds; iron pipe, 2 cents
ed clay, ready for use to join pipes, $6 to $8 per cubic yard; traps for
ns, $4.50, including laying; 1 square yard of sheet-piling in place

bor:

ents per hour.
cents per hour.
sts 30 cents a cubic yard above, and 60 cents below subsoil water, in-
g.
3 feet 3 inches by 2 feet 6 inches, cost $5.40 per running foot.
0 inches diameter, cost $3.08 per running foot.
to houses are laid at owner's expense.

| | |
|---|---|
| for Osdorf farm, per acre | $166 |
| g ground, per acre | 62 |
| per acre | 62 |
| age, per acre | 45 |
| acre | 335 |

arm (2,050 acres), $686,750.

## VIENNA.

### A.—STATISTICS OF LOCALITY.

### 1. *Population.*

| | |
|---|---|
| | 730,000 |
| sewers, over | 1,000,000 |

### 2. *Area.*

| | | |
|---|---|---|
| 50 hectares) | acres.. | 10,379 |
| 6,300 hectares) | do .. | 15,568 |

### 3. *Dwellings.*

| | |
|---|---|
| | 12,274 |
| lings | 143,617 |

### 4. *Water supply.*

| | | |
|---|---|---|
| amount that can be delivered | gallons.. | 29,847,933 |
| nsumption | do .. | 16,441,985 |
| sumption | do .. | 12,705,182 |

ountain creeks in covered aqueducts, by gravity.
estic purposes per head per day, 16 gallons.

### 5. *Mortality.*

| | |
|---|---|
| | 28.2 to 38.7 |
| years | 30.6 |

### 6. *Meteorological.*

| | Fahrenheit. |
|---|---|
| ean annual | 49.46 |
| ture | 101.84 |
| ture | —13.90 |
| temperature, annual | 93.02 |
| temperature, annual | 4.82 |
| re, summer months | 67.10 |
| re, winter months | 31.00 |
| ge of temperature | 94.10 |

Mean yearly rainfall, 22⅓ inches.
Maximum yearly rainfall, 31 inches.
Average yearly number of rainy days, 144.1.
Penetration of frost, 27 inches; maximum, 32 inches.

### II. IN STREETS, ETC.

### 1. *Shape and size of sewers.*

Pipe sewers are not used, but will shortly be introduced for house branches The shape of the sewers is oval, the invert is rather flat with a radius but a littl ahan that of the arch. The older sewers, especially those carrying creeks, a various shapes, generally with a level bottom and semicircular arch. The de less likely to block up a flat bottom than a semicircular one. The sewers a sufficiently large to be entered, which requirement determines their minimum The capacity is calculated according to Darcy and Bazin's formula, in the follo form:

$$\text{Mean velocity per second} = \sqrt{\frac{\frac{\text{sect. area}}{\text{perimeter}} \times \text{sine of slope}}{A + B\frac{\text{perimeter}}{\text{sect. area}}}}$$

A = .00019; B = .00013.

Formerly Eytelwein's formula was used. The maximum rainfall calculated to provided for is over 1 inch per hour, supposing ⅝ of an inch to get into the sewers, and to fill them only to the spring. The sizes are divided into types, with the dimensions as follows, in meters:

| Type. | Height at key. | Width at spring. | Invert radius. |
|---|---|---|---|
| I | 1.10 | 0.80 | 0.338 |
| II | 1.26 | 0.84 | 0.35 |
| III | 1.35 | 0.90 | 0.367 |
| IV | 1.50 | 1.00 | 0.42 |
| V | 1.65 | 1.10 | 0.45 |
| VI | 1.80 | 1.20 | 0.50 |

For house branches the size ordinarily used is:

| | | | |
|---|---|---|---|
| VII | 1.05 | 0.60 | 0.22 |

Large sewers, with spans to 20 feet, with flat bottoms, are used for carrying old creeks.

Maximum rainfalls:

| | | Inches per minute. |
|---|---|---|
| 1853. | June 23: 22.4 millimeters in less than 60 minutes | 0.0150 |
| 1854. | July 19: 21.4 millimeters in less than 60 minutes | 0.0140 |
| 1860. | May 2: 48.9 millimeters in 110 minutes | 0.0175 |
| 1870. | July 18: 40.6 millimeters in 140 minutes | 0.0114 |

### 7. *Topographical.*

Situate on the right bank of the Danube, which flows in a southerly direction. The city is intersected by the Donau Canal, a branch of the river, leaving it above and reuniting with it below the city, and a small river called the Wien, discharging into the "canal." The surface between the latter and the Danube is almost a level, and is 13 to 18 feet above low water. The rest of the city is on a gradually sloping and undulating ground, closed in by hills. The highest point in the city is 223 feet at ow water is 497 feet above the sea. Several creeks issuing from the nerly passed through the town, but are now converted into sewers. onau Canal is 10.4 miles; its width at low water is 140 to 180 feet; its low water is 3,709 cubic feet per second; at high water, 22,428 cubic feet

### 8. *Physical.*

rritory between the canal and the river is mostly open; a small district mer is built up. In the northwest, the ground is as yet unimproved or h scattered buildings. In the southwest, the territory is converted into ter). The greatest part of the city lies to the west of the canal; the older losely built up, and has quite narrow streets. This part is surrounded by old line of fortifications—1,000 to 1,500 feet wide, called the "Ring," ow a comparatively open space, containing promenades and the main gov- nd other buildings. Outside of the "Ring" the territory is again closely all directions to the limits of the town. The pavements are granite blocks, tly have been replaced by asphalt to some extent. In open territory they lam.

## B.—MANAGEMENT OF PUBLIC WORKS.

blic works are under a "general director." The separate departments are as

rchitecture, for public buildings and grounds.
Vater supply.
livers, canals, and sewerage; headed by a chief engineer, with a staff of two al assistants, one for each half of the city, eight assistants for general design intenance, and a large staff of clerks and inspectors.
Streets and bridges, and
Fire department.

yearly budget is about $8,000,000. New works, as well as the maintenance of ng works, are done by contract.

## C.—DESIGN AND CONSTRUCTION OF SEWERAGE WORKS.

### 1. *General system and alignment.*

ombined water-carriage, with some dry removal, which is gradually being aban- ed. System is not satisfactory on account of many old and improperly designed ks. New works are gradually replacing and supplementing them. Since 1859 the ation has received systematic treatment. All sewage discharges into the Donau al. At present there is a project to build an intercepting sewer along its entire tern bank, discharging into the Danube several miles below the city. The Wien ver is preserved from contamination by an intercepting sewer on each shore; a rd one protects the extensive flat ground in the south from the storm-water of the joining high grounds. The rest of the sewers are along the valley lines, several of em inclosing creeks originating in adjacent mountains.

### 2. *Depth and grade of sewers.*

The depth of sewers below the pavement varies in general from 10 feet to 15 feet. The grades, on account of the undulating surface, are as a rule very good. The aximum grade is 0.027 (1 : 37). The minimum grade is 0.0016 (1 : 608). The grade for e intercepting sewers is 0.0022 (1 : 455). The common grades for ordinary sewers re about 1 : 100.

### 3. *Junctions, connections, overflows, outfalls.*

Junctions of sewers are usually built at 45°, or are tangential, with comparatively all radius. Sewers which are too large ever to get filled join the others at 70 to 90. The house branches usually terminate at right angles, as in Paris.

Overflows are built at various places in the two intercepting sewers along the Wien ver.

or the proposed main interceptor along the Donau Canal, overflows will be put osite every valley-line sewer discharging into it.

ll the present outfalls are along the Donau Canal at different elevations, varying m mean to ordinary high water. They are unsightly and obnoxious.

### 4. *Ventilation.*

Ventilation is had by open grates in the manholes and partially through soil a water pipes of houses.

Odor in the old sewers, particularly those built of rough masonry, is very strong at all times. The odor in the new brick sewers, and especially in the concrete sewers, is, on the other hand, very slight.

### 5. *Man and lamp holes, flushing shafts.*

Manholes are usually 2 feet square in section, 63 × 63 centimeters, increasing in size towards the bottom, if very deep. They are placed at intervals of about 200 feet apart and are all ventilating. Usually they are built directly over the sewers, but in very frequented streets they have side entrances from the sidewalks. The grating has holes 2 inches square by 3 inches to 4 inches deep, with one-half inch of metal between. The iron stepping-rods are placed across the corners. There are no lampholes nor flushing shafts in use.

### 6. *Gullies.*

The gullies vary in design with the inlet. They are sometimes vertical, in the curb (Paris), with an opening 4 inches by 12 inches, and sometimes horizontal, in the gutters, and covered with a grating. The latter is usually square in plan, measuring from 12½ inches to 18½ inches. Many gullies are supplied with catch-basins, especially in the suburbs, and they are rarely trapped. The connection with the sewer is by a branch, 3 to 4 feet high, having a good slope and a rectangular junction with the larger sewer.

The gullies are placed in the block, not at street corners. The curbs are 12 inches to 14 inches broad, and their height above the gutter is generally 3 inches to 4 inches.

### 7. *Pumping-stations.*

No sewage is pumped.

### 8. *Miscellaneous.*

* * * * * * *

### 9. *Materials and construction.*

Sewers are built of bricks and concrete. Pipes are also to be used in future.

Bricks are of the best and are ordinary and wedge-shaped. In the arches both kinds are used in alternating courses. Dimensions of the Austrian bricks are 11½ by 5½ by 2½ inches. The brick-work is built of concentric rings, between which is a heavy coating of cement to render the work water-tight.

Concrete sewers are built in preference whenever the cost is not too great. The centers are made of planed castiron, which gives the sewers a great degree of smoothness. The best Portland cement is used, in the proportion of 1 to 2 of sand and 5 of stone Cement is carefully test the for every work.

### 10. *Statistics.*

| | Yards. |
|---|---|
| Length of main sewers | 59,308 |
| Length of ordinary sewers | 191,933 |
| Length of house branches | 429,800 |
| | 681,041 |

Or, 387 miles.

## III. IN HOUSES.

Cess-pools are being abolished and water-closets introduced.

House branches (passage-ways, as in Paris) are built from the sewer to the house. They are 6 feet to 3 feet 3 inches high and 2 feet wide. The excrements and the house water are turned into them, but on account of the slight fall they deposit, and must be drawn into the sewer with a scraping tool. It is urged at present to substitute vitrified pipes for house branches.

Up to 1867 they were cleaned at the owner's expense; since, they are cleaned by the city. The length of these brick passage-ways is 245.4 miles.

| | |
|---|---|
| Number of cess-pools still remaining | 836 |
| Number of buildings connected with sewers | 10,100 |

## IV. DISPOSAL OF SEWAGE.

The solid matter that is taken from the house branches and sewers, also the contents of cess-pools, are filled into barrels and carted to the "canal," where they are placed on lighters and towed to its junction with the Danube and there discharged into the current.

Sometimes small quantities are sold for a trifle as manure.

The sewage discharges into the canal.

At low-water its pollution is estimated at one part sewage to 3,500 parts river-water, ordinarily it is one part sewage to 5,800 parts river-water. Interception and discharge into Danube is contemplated.

## D.—MAINTENANCE OF SEWERAGE WORKS.

### 1. *Appliances.*

The contents of cess-pools and the cleanings from the sewers are removed in casks of wood, strongly built and provided with tightly-fitting covers. These are again removed on boats or scows specially constructed for the purpose. Both casks and boats belong to the city. Besides, ordinary scraping and loading tools are used for cleaning the sewers.

### 2. *Method.*

The house-passages or drains are cleaned by the city, as well as the sewers, the whole of which is done under one contract. The inspection is very thorough. The cleaning is done at certain fixed periods. House-passages are scraped out once a month, cess-pools are emptied when they are three-quarters full. Sewers are cleaned at intervals varying with their grade. Those with a fall of less than 5 feet per 1,000 are cleaned once a month, those with 5 to 10 feet per 1,000 every two months, all over 10 feet per 1,000 every three months. When deposits reach a greater depth than 3 inches, a special cleaning at intermediate times is required.

Besides this regular cleaning, special cleaning may be done on private complaints. The inspectors must walk through the sewers of their districts and examine them after each cleaning and report condition. Full records are kept of this work both for sewers and houses.

The cleaning is done at night between ten and five o'clock, in winter to six o'clock, and its extent is daily reported.

All filth, rubbish, &c., is loaded into casks and carted to the canal, where it is placed upon boats, towed to the Danube, and there discharged. In the winter it is carted to the Danube and discharged opposite the city. The casks must be quite filled and the empty ones returned in a clean condition. The cess-pools are emptied by pumping the contents into casks. After the cleaning of house-passages, they are slightly flushed with water. Sewers have no flushing arrangements, such as pen-stocks, movable dams, &c., although they are contemplated for the future. The contractors for maintaining the sewers have also to free the outfalls in the Wien River or canal from objectionable accumulations.

Payments for cleaning are made in a gross sum for the year, with proportionate increase or decrease for new or abandoned sewers or drains.

In 1879 there was a length of 820 miles of sewers cleaned.

## E.—COST OF SEWERAGE WORKS.

### 1. *Management and maintenance.*

| | |
|---|---|
| Annual cost of cleaning sewers | $42,475 |
| Annual cost of cleaning house-drains and cess-pools | 63,700 |
| Annual cost of repairing sewers (owing to many being old and dilapidated) | 20,000 |
| | 126,175 |

The payments for new sewers are divided, so that property-owners bear one-third, i. e., one-sixth on each side of street, and the city two-thirds of the expense.

The payments for cleaning house-drains, passages, and cess-pools are made by city, but the amount is reimbursed by owners in proportion to assessed value of property.

### 2. *Construction.*

| | |
|---|---|
| Cost of sewers up to 1880, about | $4,600,000 |

## LIVERPOOL.

### A.—STATISTICS OF LOCALITY.

#### 1. *Population.*

City proper..........
Water supply and drainage district..........
Average density per acre..........

#### 2. *Area.*

City proper..........acres..
Water supply and drainage district, about..........do...

#### 3. *Dwellings, &c.*

Number of houses in city, about..........
Inhabitants per house..........

#### 4. *Water supply.*

From small rivers, creeks, and a few wells, averages 17,750,000 gallons per
32.3 gallons per head.

#### 5. *Mortality.*

Mean for twelve years..........
In 1879..........

#### 6. *Meteorological.*

Fah

Temperature, mean (1878)..........
Maximum (1878)..........
Minimum (1878)..........
Mean of daily maximum (1878)..........
Mean of daily minimum (1878)..........
Rain, 189 days (1878)..........inches..
Mean humidity (1878)..........

Greatest observed rainfall, .75 inches per hour, or 0.013 inches per minute.
Frost, mean, 18 inches; maximum, 24 inches.

#### 7. *Topographical.*

Situate on right or east bank of river Mersey, a few miles from its mouth. Th is upon undulating ground, which rises rapidly toward the east and northeast, rea elevations of 175 feet in the northern and 248 in the southern part.

The entire river front is taken up with extensive docks. City datum is 5 fe low mean tide.

Tides in Mersey:

Extraordinary high tide, + 25 feet.
Average high water, equinoctial spring tides + 21 feet 1 inch.
Mean high water, + 15 feet 6 inches.
Mean tide-level, + 5 feet 0 inches.
Mean low water, — 5 feet 6 inches.
Average low water, equinoctial spring tides, — 10 feet 4 inches.

#### 8. *Physical.*

The central and eastern parts are closely built up, also those along the river.

The southeastern parts contain the parks and much garden area.

The streets have granite and trap-block pavements of excellent quality, and a quantity of wood pavements.

#### 9. *Geological.*

The city is located an red sandstone, which generally rises to within a few f the surface. At places it is covered with loam and gravel.

4

COOPER
MEDICAL
COLLEGE

avation for sewers is usually in rock, but this is generally soft enough to be d or wedged off.

## B.—MANAGEMENT OF PUBLIC WORKS.

city engineer is in charge of sewers, streets, including tramways, and the registn of property. He is assisted by 15 engineers and 25 clerks. There is 1 chief tor and 5 district inspectors, each with several foremen, for maintenance and tion of sewers and house-drains.

water supply is under a special department, with chief engineer and corps.

## C.—DESIGN AND CONSTRUCTION OF SEWERAGE WORKS.

### I. GENERAL SYSTEM AND ALIGNMENT.

mbined water-carriage with discharge directly into river. The alignment of the sewers is a combination of interception and valley-line drainage. There are nine ts into the river along a front of 5 miles. Two sewers, one discharging at each of xtreme ends of the city, nearly follow the municipal boundary until they almost , after encircling the town, at an elevation of 200 feet. They are intercepting rs for the greater part of their length. The water from the rapidly sloping ground e northern part of the town has also been intercepted by three mains, to prevent cumulation and flooding the flatter districts, but lower down they are valley-line rs. The extensive series of connected docks fronting the city has also made inption advisable along the wharves to a great extent, and with but few outlets. remaining sewers act as natural valley sewers.

e system of alignment pursued with regard to the house is the so-called "back age," by which the sewers are led through the back alleys instead of the front ts, and thus not necessitating the house pipes to pass through or under the cellars, pt in rare cases.

e lowest portions of the sewers are regularly filled with back-water, on account e great tidal range, but they have a good grade and discharge completely above tide.

### II. IN STREETS, ETC.

#### 1. *Shape and size of sewers.*

l sewers are egg-shaped, except a few outfalls, which are circular. Pipes (9 es and 12 inches diameter) are rarely used, except in the back passages and for e connections.

e sizes of sewers are calculated according to Eytelwein's formula, when necessary, s the outlets are all constructed, it is preferred to use judgment and proportion rding to sewers already built. The least and ordinary sizes are 3 feet by 2 feet foot 10 inches. The invert is formed by a 6-inch radius. The largest sewers are t by 4 feet, save a few in the dock estate, which are 7 feet by 6 feet.

#### 2. *Depth and grades.*

he depth of sewers in the street is from 13 feet to 14 feet; in back passages from t to 12 feet.

he grades of the sewers, owing to the topography, are rather heavy, ranging ordily from 6 inches to 2 feet and even 3 feet per hundred.

#### 3. *Junctions, connections, overflows, and outfalls.*

unctions of large sewers are usually made in a chamber covered by a funnelped arch. Pipe-sewers are joined in manholes. When pipe-sewers from back ets or houses join a brick sewer, they are brought in at 45°, either by a slant pipe block.

he connecting pieces are built into the sewer opposite every house and back street; ot directly used they are temporarily closed by a plate cut out of slate.

here are no overflows, as most of the sewers are along the valley lines, or are suffntly large to take all of the rain-water.

he outfalls into the river, of which there are 9, discharge from the end of piers ctly into the Mersey at different elevations. Six of them have elevations varying n 8 inches above to 5 feet 4 inches below mean low water; 3 from 10 feet 3 inches 11 feet 4 inches above mean low water.

### III. IN HOUSES.

-pools have been abolished and carefully cleaned and filled up. Water-carriage )ulsory for all houses.

s for the house drainage are subject to the approval, and their execution to the :ion, of the department.

system of back drainage is preferred, by which the house pipes run to a back ıto 12-inch pipes, which discharge into the brick sewers on the street.

main pipe of the house is usually 6 inches in diameter, sometimes 8 inches and s. Pipes are rarely laid under or through the houses.

-water and soil-pipes are carried down outside the house, the first into a disting manhole, the latter directly into the sewer, and its other end is taken above res. Water-traps are used against the soil-pipe; the disconnecting manhole ped against the sewer.

### IV. DISPOSAL OF SEWAGE.

ewage is discharged outside of the docks into the Mersey at all times. The of water passing the city at both tides is too great to make any pollution ble.

## D.—MAINTENANCE OF SEWERAGE WORKS.

### 1. *Appliances.*

rs are cleaned almost entirely by flushing. Pen-stocks are used for the larger iron flush-tanks mounted on wheels and holding 250 cubic feet for smaller

l trucks gauged to run on the inverts and to carry silt-buckets, also small s placed on wheels to lift them out are used.

### 2. *Method.*

y sewer is flushed at least once in three months. The good grades do not allow leposit. In a few localities, especially where heavy grades change to light ones, rers must be cleaned by hand.

highest sewers are generally flushed first. The flush-tanks are taken above the le or shafts, and their contents (250 cubic feet) are discharged through an g in the bottom in fifteen seconds. Where flushing does not suffice, the silt, is mostly sand, is thrown into buckets placed on small trucks in the sewer, to the manhole and lifted out by means of a small transportable derrick. The are in a fair condition. There is much repairing done to the inverts on heavy and to the older sewers, to give them regular and smooth surfaces.

## E.—COST OF SEWERAGE WORKS.

### 1. *Management and maintenance.*

rtment expenses for maintaining and repairing sewerage works are about 0 annually.

ıal cost of flushing sewers, alone, $20,000.

### 2. *Construction.*

verage cost of a 3 feet by 2 feet sewer, with 21 feet depth of cutting, is $5 per g foot.

r is paid for at $6 per week.

s, ordinary and wedge-shaped, average $7.20 per 1,000.

e-connecting blocks cost $1.70 apiece.

## HAMBURG.

### A.—STATISTICS OF LOCALITY.

#### 1. *Population.*

Hamburg State ..................................................
City proper, including Altona ..................................................
Built up and sewered portion of Hamburg alone ..............................
Inhabitants in old city ..................................................
Density of population in southeastern section ....................per acre..
Density in other sections decreases to ..........................per acre..
Average density for city and suburbs ..........................per acre..

#### 2. *Area.*

Hamburg State ..................................................acres..
Built up area of city ..................................................acres..
Area sewered ..................................................acres..

#### 3. *Number of houses.*

Total, about ..................................................
In old city ..................................................

In old city: average number of dwellings per house, 6.5, and 4.3 per
dwelling.

#### 4. *Water supply.*

From river Elbe, filtered.

Consumption, maximum ........................................cubic meters.
Average ..................................................cubic meters.

Daily average, 46 gallons per head.

#### 5. *Mortality.*

Average for 10 years ..................................................
1879 ..................................................

#### 6. *Meteorological.*

Temperature, yearly mean ..................................................
Greatest maximum ..................................................
Greatest minimum ..................................................
Mean of maximum, summer months ..........................................
Mean of minimum, winter months ..........................................
Ordinary yearly maximum ..................................................
Ordinary yearly minimum ..................................................
Mean range yearly ..................................................

Average yearly rainfall (10 years) 27¾ inches.

Greatest observed rainfall, 21 millimeters in 45 minutes, 0.0184 inch per

Frost penetrates usually 1 meter (40 inches).

Prevailing winds, west.

#### 7. *Topographical.*

Situate on right and north bank of the river Elbe, about 63 miles above its
The city is bisected by a creek, the Alster, which has been transformed int
gable canal in the central city, and forms two lakes (basins) in the norther
the city. The western and northwestern sections of Hamburg comprise the
tricts (Geest), reaching elevations of 230 feet; the eastern section is low
great extent guarded against high tides by dikes and relieved of subsoil
wind-pumps.

Backflow of high tide into the Alster is prevented by two dams, now street
the valley at 12 feet 3 inches above ordinary high water. The level of th
basins is kept constant at 5 feet 1 inch above ordinary high water.

Mean discharge of Alster is 160 cubic feet per second.

Minimum discharge of Alster is 70 cubic feet per second.

ERAGE WORKS IN EUROPE. 1880.

| | |
|---|---|
| rdinary high water of Elbe above datum | +17′ 9″ |
| rdinary low water | +10′ 9″ |
| rdinary mean range | 6′ 1″ |
| lighest known tide, 1825 | +28′ 8″ |
| owest known tide | + 1′ |

Discharge of northern arm of the Elbe at low water is 3,532 feet per second.

### 8. *Physical.*

Densely built-up sections, with narrow streets, are situated near the Elbe and eastn part of the town. In the northwest part there are considerable spaces quite open, d used as parks, promenades, zoological garden, &c.

Streets in the newer sections are of moderate widths. Pavements are of granite ocks. The suburbs are open, with much garden area and macadamized roads.

### 9. *Geological.*

The southern and old part of the city is built on alluvial sands and clay; the westn and northern part, in the higher sections, consist of diluvial and tertiary formaons cropping out as sand, gravel, clay, and marl; the eastern, low and marshy disicts, are formed of heavy deposits of sand and peat.

## B.—MANAGEMENT OF PUBLIC WORKS.

Public works are under control of a building commission, consisting of 3 members f the Senate and 10 private citizens.

There are three departments: I. River and harbor works; II. City water supply; nd III. Architecture and engineering. The latter is divided into two sections: *a.* rchitecture, which is under the supervision of a chief architect and director for all ublic buildings, with 6 architects, 1 registrar, 2 clerks, and attendants.

*b.* Engineering, for the design, construction, and maintenance of streets, parks, ridges, and sewers, and for surveys. This section is superintended by a chief engineer (who is also chief engineer for the water supply department, II). There are 5 ssistant engineers, 1 registrar, 2 clerks, &c., at a central bureau, besides a staff for districts of the city consisting of 4 division engineers, 5 clerks, and 10 inspectors. In addition, there is a survey bureau, with 1 chief surveyor, 1 chief clerk, 11 surveyrs, and 2 draughtsmen; also a bookkeeping bureau for engineering section with 1 ecretary, 1 bookkeeper, 2 clerks, and 1 messenger. Besides this staff at the offices, here are 72 foremen, flushers, keepers, &c., for maintenance of sewerage works. The atter are generally built by contract.

Water supply is not furnished on streets without sewers.

## C.—DESIGN AND CONSTRUCTION OF SEWERAGE WORKS.

### I. GENERAL SYSTEM AND ALIGNMENT.

Combined water carriage with discharge into the northern arm of the Elbe. From he irregularity in the topography, the alignment is somewhat complicated. There re four drainage districts. The old city, drained between 1843 and 1860, with direct utlets into the river; the Geest system, more recently built for the areas draining nto the Alster basins; the Hammerbrook flats, which are below high-water level and rom which the sewage is pumped and discharged through the Geest main sewer; and, nally, the valley which forms the boundary between Hamburg and Altona. The eest system is intercepting, the Hammerbrook is radial, the rest are valley-line sysems. The sewers can nearly all be walked through, pipe-sewers being rarely used, xcept for house-branches.

Dead ends are avoided as much as possible (Lindley principle) by connection with ther sewers or stacks. System was designed by Mr. W. Lindley in 1843. Recent orks by Mr. A. F. Meyer.

### II. IN STREETS, ETC.

### 1. *Shape and size of sewers.*

Pipes are used only for house drains. Brick sewers are all egg-shaped, except the tercepting sewers, which are circular. The size is calculated according to Eytelin's formula, the data being a rainfall of 25 millimeters (1 inch) of rain in 24 hours, of which two-thirds is to flow into sewers. This refers mainly to the intercepting sewers. The minimum sizes of the ordinary sewers are large enough to be walked through, while, on the other hand, overflows into the Alster or canals are provided wherever possible. The amount of sewage calculated is 39¼ gallons per head per day, one-half to flow off in 9 hours. The sewers are divided into 10 classes, according to size. The largest (Geest main collector) is circular and 10 feet in diameter; the rest range from 8¼ feet by 7 feet to 3 feet by 2 feet.

### 2. *Depth and grade.*

The depth of the sewers is generally 10 to 16 feet below the pavement. In Altona it averages 10 feet. The minimum grades are 1 : 3,000, which is the grade of the Geest main sewer for nearly 8 miles. When half full it has a surface velocity of 1 meter per second. The smaller sewers have grades up to 1 : 100, in some cases even more.

### 3. *Junctions, connections, overflows, outfalls.*

The junctions of sewers are made with funnel arches and easy curves.

Connections with house drains are made with pipes at the spring, set in at an angle.

Overflows are placed at various points along the Alster basin and the canals.

The outfall sewers into the Elbe are provided with self-closing gates, to prevent flood-waters from backing into them. They act then as reservoirs for the sewage.

In case of prolonged high water in the river the entire sewage can be run into the canals, and thus relieve the sewers.

The outfalls of the Geest main sewers and others are submerged and discharge into the current through timber twin sewers 220 feet and 130 feet long, sunk to a depth of 21 feet below low water.

### 4. *Ventilation.*

The ventilation is very thorough. The man-holes are ventilating, and between them 120 to 340 feet apart, are special shafts for ventilation, 12 inches diameter, covered by a square grating. The street inlets are all without traps, and the soil and rain-water pipes of the houses also act as ventilators. The odor in the Hamburg sewers is very slight, and rarely perceptible at the surface openings.

### 5. *Man-holes, lamp holes, flushing-shafts.*

Man-holes are circular, .93 meters (3 feet) diameter, and are placed 350 to 450 feet apart. In frequented streets they always have side entrances with double cover (London). In others the man-holes are directly over the sewer. The cover is an open grating with no basin to catch dirt. There are no lamp-holes nor flushing-shafts used.

### 6. *Gullies.*

They are situated in the gutter having a horizontal grating, 17 inches by 15 inches. The depth of curb at the inlet is 7 inches, at other points it diminishes to 4 inches and 3 inches. There are two different designs, one with a catch-basin, for streets having macadam in the center, the sides only being paved, and one with a circular neck leading from the grating by a vertical curve directly into the sewer, for all streets completely paved. The catch-basin, in the first case, is 17 inches square, it is 4 feet deep below the surface and 16 inches below the outlet, which is a terra-cotta pipe 9 inches diameter leading into the sewer. The more common inlet is the circular neck, 12 inches diameter, built of brick. To fit it properly at the surface the iron box holding the grating is drawn in at the bottom to form a circle also of 12 inches diameter. All inlets are without traps. It is usual to put a man-hole or ventilating-shaft near the gully, so that the circulation in the latter is generally downward, their connection with the sewer being at the spring. Inlets are generally placed 140 feet apart and rarely at street intersections.

### 7. *Pumping-stations.*

All the sewage from the Hammerbrook lowlands is pumped into the Geest intercepting sewer by two engines of 60 horse-power, each driving one centrifugal pump and raising the sewage 8 feet 10 inches. The works have only recently been finished.

### 8. *Miscellaneous.*

The sewage crosses the Alster and the canals at various points by inverted siphons of cast and wrought iron, and also one of masonry. They have caused no troubl in any way.

### 9. *Materials and construction.*

s are all built of bricks of good quality, pipes being used only for house con-
ı. The courses of bricks are concentric rings with a coat of strong mortar
ı, to make them impervious to water.
ırger sewers, from 5 feet 6 inches to 8 feet 6 inches high, have three courses in
ɪrt, extending above the spring. The Geest main sewer, circular and in tun-
four complete rings. The sizes smaller than 5 feet high have two rings.
ɪhaped bricks are used for the inside ring of the arch and invert. The con-
of the inlets with the sewers is made of pipe when they have a catch-basin
l, of a 4-inch ring of brick when leading directly to the sewer.
ıbmerged sewer-outlets are of timber, securely framed and bolted.
ınd cement is used for mortar, in proportion of 1:3 of sand.
ɔrk is done by contract. Sewers are bid for by the running meter, with unit
ttached for a variation of original quantities.

### 10. *Statistics.*

ngth of sewers:

| | Yards. |
|---|---|
| n and intercepting | 26,889 |
| nch sewers | 202,931 |

leest main collector is 3,390 yards long and tunneled for nine-tenths of its
It receives the sewage from 200,000 persons, including 35,000 water-closets.
ers of Altona are 27,888 yards long.

### III. IN HOUSES.

ɔols are prohibited. Where there are no sewers, casks are ordered for the re-
and removal of excrements. Their number is quite small. Where sewers are
treet or being built, connection for sewage and rain-water removal is com-
Water-closets are not obligatory, but almost always used.
ouse pipes are laid up to the curb line by the department. The remaining
y be done by the owner, but under its supervision.
pipes must be of iron, vitrified clay, or cement. All closets, sinks, bath-
ashstands, &c., must each have a secure trap. The soil pipes are carried
the roof for sewer ventilation.

### IV. DISPOSAL OF SEWAGE.

wage is discharged into the Elbe, under water, into the current.
ɜwers from Sanct Pauli and Altona discharge above highest tides; the Geest
wer and the others at ordinary high water. When tides rise above + 17 feet
s their lower ends act as temporary reservoirs for sewage. The quantity of
ischarged by the Norder Elbe, which receives the sewage, is 131 cubic yards
ınd at low water. For a population of 800,000, by calculating 52.8 gallons per
r day, there are 528 gallons of sewage per second, which gives a proportion of
ewage to 50 parts river-water, even with this unfavorable selection of data.

## D.—MAINTENANCE OF SEWERAGE WORKS.

### 1. *Appliances.*

s are almost exclusively cleaned by flushing. Pen-stocks, gates, &c., are used
ent patterns; some are raised vertically, some are hinged on the side, with
r for the smaller and two for the larger sewers. They are placed at intervals
ng 500—1,000 feet apart.

### 2. *Methods.*

s below the level of the Alster basin, which is 11 feet above low tide in the
e flushed with its water, which is led into the system at various points. The
bove the level are flushed by a continuous damming up of the sewage. Water
city supply is seldom used. At the highest points of each system the sewers
servoirs for subsoil water, which is stored and used for flushing.
w sewers of the Hammerbrook are flushed by water from the canals. The
is done by day's work by the department. There are twenty flushers (1 man
les of sewers) who attend to it, including the closing of tide-gates.
wers are inspected and flushed at least once every three months, when a de-
turn of their condition is made. The greater number are inspected every 9

**to 10 weeks. Sewers below the Alster basin are flushed regularly twice a week, according to necessity. The men begin to flush at the lower end and work up The sewers are unusually clean, although many have been 30 to 35 years in us disagreeable odor was perceptible in a 4-foot sewer 4 days after flushing.**

### E.—COST OF SEWERAGE WORKS.

#### 1. *Management and maintenance.*

Department for engineering, annual:

| | |
|---|---|
| Salaries at office | $ |
| Pensions | |
| Office expenses | |
| Maintenance of sewers | |
| Pumping station, Hammerbrook | |
| Other works of department | 4 |
| General expenses, printing, library, &c | |
| Total | 5 |

Assessments upon properties for sewer construction are as follows: If prop improved it is $1.58 per foot front; if unimproved, 68 cents per foot front, bu an additional payment at the time of improvement. For corner lots payment lected only from the larger front. If a division of property subsequently take a readjustment of the assessment is required, and respectively an additiona ment. Corner lots bounded by sewers on three sides pay for one front only, i larger than the two others. If it is equal or smaller, the assessment is col from the two shorter sides. If the property runs through a lot to another stre sewers are built on both, the owner pays only for the larger front of the two, he has a connection to both sewers. If connection was made at the shorter side upon building the sewer on the longer side the difference is collected. If prop entirely surrounded by streets having sewers, it is considered like two corne payment being collected for the two longest fronts.

Property-owners pay $1.50 for making the sewer connection; also the cost pairing sidewalks.

#### 2. *Construction.*

| | |
|---|---|
| The main sewers have cost | $1,8 |
| The branch sewers | 2,3 |
| Total | 4,2 |

The sewers of Altona have cost $259,500.

---

## FRANKFORT ON THE MAIN.

### A.—STATISTICS OF LOCALITY.

#### 1. *Population.*

| | |
|---|---|
| Year 1880 | 1 |
| Contributing to sewers | |

#### 2. *Area.*

| | |
|---|---|
| City, including river | |
| Closely built up sections: | |
| North of river | |
| South of river | |
| Suburbs, north of river | |
| Suburbs, south of river | |
| City parks, promenades, and gardens | |
| Farm land and meadows | |
| River | |
| Area supplied with sewerage | |

#### 3. *Dwellings, &c.*

| | |
|---|---|
| Number of houses | |
| Number of dwellings to one house, average | |

### 4. *Water supply.*

m mountain creeks by gravity. Average daily quantity, 4,226,000; 31 gallons head.

### 5. *Mortality.*

| | |
|---|---|
| -1830 | 24.5 |
| -1840 | 22.0 |
| -1850 | 19.9 |
| -1860 | 17.6 |
| -1870 | 19.1 |
| -1880 | 21.0 |

### 6. *Meteorological.*

| | Fahrenheit. |
|---|---|
| perature, mean annual | 49.60 |
| est monthly average (July) | 67.30 |
| est 5-day mean (July) | 68.86 |
| st monthly average (January) | 31.80 |
| est 5-day mean (January) | 30.40 |

vailing winds, southwest.
st penetrates usually 40 inches; in 1880, January, 52 inches.
erage rainfall, 2 inches.
ximum rainfalls:
1873, July 6, 30.5 millimeters in 60 minutes=0.0201 inch per minute.
1875, July 4, 40 millimeters in 100 minutes=0.0157 inch per minute.
1876, April 2, 18 millimeters in 40 minutes=0.0177 inch per minute.

### 7. *Topographical.*

uate on both banks of river Main, 21 miles above its confluence with the Rhine. river runs westwardly, and the main part of the town is on the northern bank. e ground rises gradually from the river, which, during freshets, floods consider- portions. It then forms a plateau on both sides of river, rising from 15 to 30 above low water. In the extreme northern and southern parts of the town the nd rises rapidly several hundred feet. The mean flow of the Main is estimated ,180 cubic feet per second. Low water at Frankfort is 294 feet above sea.

### 8. *Physical.*

The old city, which forms a comparatively small part, is very densely built up, h very narrow streets and no garden areas. The newer districts and the suburbs open, with gardens, public and private; on the site of the old fortifications and st are promenades surrounding the city. Streets are paved with stone blocks; in suburbs they are macadamized.

### 9. *Geological.*

The lower districts are formed of layers of alluvial sand (often quicksand 10 feet p), loam, and muck; the higher grounds are diluvial, with a tough yellow clay, n and sandy clay near the surface. The west end of the lower town is built on old marsh. Subsoil water is abundant, and its level, formerly higher than the wers, is now kept by them at a lower and more constant height.

## B.—MANAGEMENT OF PUBLIC WORKS.

The works are managed by several departments, each one of which is under imme- te supervision of a committee of city councils and its salaried chairman. There three regular departments: Streets and parks, Architecture, and Water-supply. e sewerage works are under a special department (temporary), also supervised by mmittee. It is in charge of a chief engineer, and is subdivided into 3 bureaus.

I. Construction and maintenance, with 8 officers.
II. House drainage, with 3 officers.
III. Surveys and registry, with 20 officers.

When works are being constructed additional engineers and inspectors are employed, ording to necessity. For maintenance of sewers, 2 foremen, 8 to 10 men, and 2 teams constantly engaged.

New works are executed under contracts, with intelligent and strict inspection.

## C.—DESIGN AND CONSTRUCTION OF SEWERAGE WORKS.

### I. GENERAL SYSTEM AND ALIGNMENT.

Combined water-carriage with present discharge into main. Sewage farms posed.

The system of alignment is that of interception. The territory is divided into the high and the low, districts. The latter is situated along the river, and cove area where cellars are affected by flood-waters; the former comprises the ter above a contour 38 feet above low water.

The high system is divided into bands nearly parallel with the river, each of is drained by an intercepting sewer near its lower contour. All the high-level ceptors unite to form a main outfall-sewer. At present it usually discharges int low-level outfall-sewer, except during times of heavy rain, when the sewage is t through an inverted siphon under the latter directly into the Main.

Storm-water overflow-sewers are carried to the river at various points. When ing the low district they are laid in the highest streets and discharge as high as p ble. The outfall for the lower system was located at a point below the town w the high water in the river is 8 feet lower than opposite the center of the town. the sewer has a less grade than the river, a lowering of the drainage level of 2 fe the lowest districts is obtained.

Dead ends are entirely avoided. Every sewer of the lower and upper syste united with one next above it, and finally, at the highest point, with a ventil stack, of which there are two, one in the eastern and one in the western part o town. The junctions of the lower with the higher system are securely guarded pen-stocks (only to be opened for flushing), to prevent a flooding of the low di by water from the upper one at high stages of the river. The system was desi by Mr. W. Lindley, and work was commenced in 1863. It is substantially compl except portions of the lower district.

### II. IN STREETS, ETC.

#### 1. *Shape and size of sewers.*

Pipe sewers are used in sizes of 12 inches and 15 inches diameter. All o sewers are of brick and egg-shaped, except some of the overflow sewers, which circular. The smallest brick sewers are 2 feet 10 inches by 1 foot 11 inches. sizes were governed by three considerations: First, by a maximum quantity of ra be carried off; secondly, by convenience of construction, as it was found prefer in the many streets which required tunneling to fill the entire space by a brick se 2 feet 10 inches by 1 foot 11 inches, instead of by a small pipe, even where the la would have been sufficiently large, and to pack the remaining space with ea thirdly, by the grade, for the convenience of cleaning. The intercepting sew are calculated to receive a rainfall equivalent to ¼ inch in 24 hours plus a daily amo of sewage of 36.7 gallons per person. The overflow sewers are intended to rem an amount equal to 6 millimeters (¼ inch) per hour, and the various other sew branching off from the main interceptors to the lower areas will carry any additi amount of rain-water that may require underground conveyance, which is seld necessary.

The formula used for calculating the capacity is, in meters:

Log. sin. of slope = log. coeff. + 1.8 log, mean velocity —1.25 log. mean radius

$$\text{or } s = c \frac{v^{1.8}}{r^{1.25}}$$

Values for coefficient $c$ are as follows:

| | |
|---|---|
| Cast-iron and terra-cotta | .00018 |
| Brick | .00030 to .00025 |

(The coefficient also increases as sewage becomes more concentrated.)

The consideration for cleaning gave the following minimum sizes:

When grade is less than 1:500, then size is at least 4 feet 8 inches by 3 feet; wh grade is between 1:500 and 1:100, size is 2 feet by 3 feet; for grades over 1:100, pi 12 inches and 15 inches diameter are the smallest sizes used.

The ordinary mean velocity in the mains is about 16 inches per second.

Subsoil water is allowed to enter the sewers at certain points.

About 15 per cent. of all sewers are 12-inch and 15-inch pipes. About 55 per ce are brick, 2 feet 10 inches by 1 foot 11 inches. About 30 per cent. are larger tha feet 10 inches by 1 foot 11 inches, and also of brick.

main northern outfall sewer is 6 feet 3 inches by 4 feet 7 inches. The main ptors are 5 feet by 3 feet 3 inches, and 4 feet 3 inches by 2 feet 9 inches, and 3 inches by 2 feet 2 inches. The branch sewers are 2 feet 10 inches by 1 foot 11 t.

### 2. *Depth and grade of sewers.*

depth of the sewers is below the lowest cellars. The ordinary depth of cellars et 5 inches, and least depth of sewers is usually 13 feet 1 inch. The greatest is usually 19 feet 8 inches. The limits in a few instances are 8 feet and 33 nd the average depth is calculated at 17 feet.

minimum grade adopted is 1 : 2,000, as, for the main low level intercepting . The grades for the other sewers vary from 1 : 1,000 to 1 : 50.

rer intercepting sewers fall from 1:800 to 1:600; upper intercepting sewers from to 1:100. When the grades are greater than 1:100, especially when the soil is pipes are used in preference to brick sewers.

### 3. *Junctions, connections, overflows, and outfalls.*

ctions of brick sewers are all made by tangential curves, with large radii, and nber with a funnel arch. They are placed at such relative heights as to bring dinary flow in each branch to the same level. Pipe sewers are joined in a man-

se connections are made with blocks built into the sewer, at an angle of dis- s of 45°. They are generally placed at the level of the ordinary flow of sewage, er to avoid a drop, and therefore irregular flow and deposit, and are built into wer at every property, and temporarily closed if not used.

ccount of the peculiar system of alignment, by which all branches are joined igher intercepting sewer, and as the branches are to a great extent built 3 feet et, or much larger than is necessary for the sewage alone, these branches can be s overflows for the intercepting sewers. Besides, however, there are special w-sewers carried down to the river at various points. They cross the inter- g sewers, generally by inverted siphons, and then receive their surplus water. passing through the low districts they are laid in the highest streets, to avoid ng. Where the main outfalls unite there is also an overflow into the river. The ls to the system, of which there are to be two on each side of the river, one for w and one for the high district, are so arranged that the high district outfalls st below the city, and discharge freely at high water, whereas the lower out- re over 3,000 feet below, in order to utilize the greater fall of the river, and ower the depth of the sewers in the town. The latter discharge freely during enths of the year. The outfall is carried 130 feet from shore on the bed of the and discharges into the current.

### 4. *Ventilation.*

ventilation is through : *a*, rain-water pipes, 4¼ inches diameter, whenever the ng is not near a garret window.

soil-pipes, 5 to 8 inches diameter, extending above roof.

treet ventilating shafts, 10 inches diameter, of earthen-ware, in all broad streets, chambers, junctions, or wherever summts occur; occasionally man-holes are lating.

Two special shafts at two of the highest points in the system. They are 115 feet and have a sectional area of several square yards.

small number of factories have agreed to draw the air for the furnaces from the s. The odor in the Frankfort sewers is exceedingly slight; even in the ventila- hafts it was not very strong on a cool and rainy October day.

### 5. *Man-holes, lamp-holes, and flushing-shafts.*

n-holes are generally built with side entrances, except in narrow streets and for ewers, when they are directly over them. In the latter case they are circular ccasionally ventilating. In the former case they have a passage-way 2 meters neter from the sewer to the sidewalk, with a shaft ascending to it which is closed louble cover, such as used in Hamburg and London. Man-holes are placed at intersections; otherwise, every 540 to 600 feet apart for sewers of 5 and 3¼ feet rger, and every 250 to 300 feet for sewers 3 by 2 feet, but generally at bends. -holes are 9 inches diameter and 100 to 120 feet apart and are placed along pipe s between the man-holes. They have a catch-basin at the surface and are ven- ng. There are no flushing-shafts necessary for the system.

### 6. *Gullies.*

Gullies are placed in the gutters and have a horizontal grating 18 inches inches. The cast-iron head is an oblong box, on which the grating is place which narrows to an elliptical funnel at a depth of 12 inches where it is 6 incl 10 inches in diameter. The head-piece rests on a terra-cotta or iron basin 18 i diameter extending 7 feet 8 inches below the surface. At a depth of 4 feet 8 i there is an outlet-pipe 6 inches diameter, which running upward for a shoi tance forms a trap. An iron bucket is placed into the basin to catch the silt. 15 inches in diameter and 2 feet 6 inches high, is perforated by a large numl holes at the top, and can be lifted out by a handle. The gullies are placed at vals of 120 to 150 feet apart.

### 7. *Pumping stations.*

No sewage is pumped.

### 8. *Miscellaneous structures.*

At the highest point of each system is a flushing reservoir in which the s water is collected and stored. There are four in number and they are circular o shaped in section, vary in length from 750 to 950 feet, and are about 12 feet to 1 below surface. Their total capacity is 2,700 cubic yards.

### 9. *Materials and construction.*

The sewers are built of brick and of vitrified pipe. The materials are of th obtainable quality. They are carefully examined and every load of cement is t The materials are bought by the city and furnished to the contractors. The c is mixed into mortar by city labor.

Wedge-shaped bricks are used for arches, measuring 9¾ inches by 4¾ inches b 3 inches for all diameters, Bricks molded to circular curves (both header stretchers) are used for man-holes, and rectangular bricks with rounded edg side entrances, &c. The size of ordinary bricks is 9¾ inches by 4¾ inches by 2¼ i Brick sewers of 3 feet horizontal diameter and larger are built of two rings of (10 inches). Smaller sewers are built of one ring. Invert blocks are quite gen used. They are of terra-cotta mostly; now, concrete is preferred and cut stan on curves.

Great care is taken to make the inside surface of the brick-work as smooth a sible by careful lining, accurate centers, and smooth joints. Where the subsoil-was high, parts of the sewer were laid dry. The reservoirs for collecting s water are laid dry up to the springing line.

Pipe sewers are built of carefully selected and gauged lengths. Half-socket are preferred to others. The joints are made with well puddled blue clay, with mortar. The mortar is mixed of Portland cement and river sand in prop of 1 : 4.

A large portion of the sewers was built by tunneling on account of their dept narrow streets, and the uncertainty of the soil.

Connection-blocks for house drainage are rectangular with a 45° inlet. Th terra-cotta, but lately some have been cast in Portland cement, which is less expe

The outlet-pipes into the Main are of cast-iron and extend nearly 50 feet on the river. The gullies are made of cast iron or molded in terra-cotta.

The work is executed under contract, the city furnishing the materials an mortar, and the whole is one of the most carefully built and uniform systems a ent in existence.

### 10. *Statistics.*

| | | |
|---|---|---|
| Length of sewers | yards.. | 1 |
| Length of gully branches | yards.. | 1 |
| Length of house branches | yards.. | 1 |
| Area drained by lower system | acres.. | |
| Number of man-holes | | |
| Number of gullies | | |
| Number of gullies when system is completed | | |

## III. IN HOUSES.

Connection with sewer is not obligatory, but when desired is subject to stri ulations under control and inspection of the bureau, up to the water-closets, and gullies.

Complete and detailed plans of house drainage must be presented for approv

The pipes are kept, according to the English principle, as much as possible o of the buildings. The soil-pipe runs beyond the roof for ventilation of the sewers. All other pipes are trapped against it. The main pipe from the sewer is 6 inches diameter, and is of terra-cotta bedded in clay or concrete 4 inches all round, or it is iron. The latter must be $\frac{5}{16}$ inch thick, coated with asphalt and jointed with lead; vertical pipes are $\frac{1}{4}$ inch thick. Soil-pipes are 5 inches diameter, kitchen pipes are 4 inches diameter, rain-water pipes also.

Grades shall not be less than 11:20, but when much steeper there is to be a vertical drop. Terra-cotta pipes must be at least 18 inches below the cellar floor and 39 inches from the nearest wall, and must be jointed with 4 inches of clay inside of the house.

No pipes are to be shallower than 4 feet below the pavement. The drains for points below the highest level of river must be shut off by flap-valves. The cesspools must be filled up after connection has been made with the sewer.

Traps against the main pipe must have a depth of $2\frac{3}{8}$ inches of water and when outside the house be 4 feet below the surface. Sixty per cent. of all water-closets used are hopper-closets. The rest are the Pan and Jenning closets.

| | |
|---|---|
| Number of houses connected with sewers | 5,400 |
| corresponding to 16,000 dwellings. | |
| Number of water-closets connected | 22,000 |
| Population corresponding to above | 90,000 |

### IV. DISPOSAL OF SEWAGE.

The sewage is now all being turned into the river. In the future, irrigation, however, is to be attempted.

The outfall is below the town and extends below the river bed into the current about 130 feet from shore.

The discharge of sewage is estimated at from 30 to 45 gallons per second.

The mean flow of the river Main is estimated at 6,180 cubic feet per second.

The discharge from the most distant points takes place by actual experiment in three to four hours.

## D.—MAINTENANCE OF SEWERAGE WORKS.

### 1. *Appliances.*

The sewers are cleaned almost entirely by flushing; it is seldom required to remove deposits by hand. Wherever practicable pen-stocks and flushing-gates are built into the works. There are now about 220 pen-stocks and 320 gates. The low-level system is guarded by 40 large additional pen-stocks, made of cast iron and fitting against planed surfaces. The small pen-stocks, which are used only for flushing, are of wrought iron and much lighter. They are operated from the top or from a side entrance. The gates are single and swing to the side.

At the head of each system a reservoir built of perforated bricks collects subsoil-water to flush the sewers below:

One at Bornheim 840 feet long, 5 feet by 6 feet, 22 square feet section.

One at Kettenhof 748 feet long, 22 square feet section.

One at Roederbruch 950 feet long, 22 square feet section.

One at Bockenheim 950 feet long, 5 feet diameter, 17 square feet section.

Temporary reservoirs are built at the dead ends of unfinished sewers. The one at the Bornheim holds 20,000 cubic feet and usually collects 10,000 cubic feet in 24 hours, in rainy weather up to 60,000 cubic feet in 24 hours.

### 2. *Method.*

The alignment is so arranged that every sewer can be flushed from a higher one or from a reservoir, and so that the entire body from the latter can if necessary be turned through any one of the lower sewers. Each one is flushed about once in three weeks, and from the upper end downward. One foreman and four to five men are constantly engaged in attending to this service. The gullies are cleaned by simply lifting out the buckets and emptying them into a cart; sometimes an after cleaning is necessary. They are cleaned by day and by night, and at intervals from three days to three weeks according to the character of pavement and the weather, but generally about once every two weeks. Three persons and one cart will clean at least 110 basins in the day or 90 in the night. At least 200 a redaily cleaned, therefore, by six men and two carts.

The works are in a very good condition.

### E.—COST OF SEWERAGE WORKS.

#### 1. *Management and maintenance.*

Department for sewerage, annual office expenses:

Construction and maintenance........................................
House drainage........................................
Surveys........................................

For flushing sewers, 1 inspector and 4 flushers........................
For cleaning gullies, 6 men and 2 teams........................

Assessment on properties for sewer construction is $2.29 per foot of fro
ner lots have a deduction, in being exempt from a tax on 66 feet of the l
When sewers are only used for rain-water the properties are exempt
any assessment. The yearly tax for water-closets is $1.50 in houses ren
than $250. In others they are free.

#### 2. *Construction.*

The cost of the sewerage works up to 1880 is $2,100,000, averaging $4.
sewer, all except house drainage included.
The cost of the different sewers in marks per meter is equal to about
of the number of centimeters, of measuring the width in clear.
Junction blocks for sewer connections cost 87 cents apiece; bricks c
per 1,000.

## DANTZIC.

### A.—STATISTICS OF LOCALITY.

#### 1. *Population.*

Entire........................................
On sewered district........................................

#### 2. *Area.*

Drained district........................................s

#### 3. *Number of buildings.*

Number in the town........................................
Number connected with sewerage........................................

#### 4. *Water supply.*

From creeks, 12,000 cubic meters daily; 32 gallons per head.

#### 5. *Mortality.*

1825–1869, average........................................
1870–1871, average (sewerage built)........................................
1872–1880, average........................................

#### 6. *Meteorological.*

Temperature, mean annual........................................
Highest monthly average (July)........................................
Lowest monthly average (January)........................................
Highest five-day average (July)........................................
Lowest five-day average (January)........................................
Prevailing winds, southwest.
Penetration of frost, 3 feet.

#### 7. *Topographical.*

Situated on the left bank of the Vistula, a few miles above its mouth, an
*of confluence* with the Mottlau. The latter divides the city into two part

7

COOPER
MEDICAL
COLLEGE.

adt on the right, the Recht and Altstadt on the left, and by branching forms in addi-on several islands in the city. A small creek, the Radaune, also flows through the wn, separating the Recht and Altstadt.

The site is low and flat.

The Niederstadt, to the right of the Mottlau, lies only 4 feet above the river, and surrounded by dams to guard against floods. The parts on the left bank of the ottlau are about 12 feet above the river, but rising to 24 feet.

Level of river above Baltic is only 4½ inches.

### 8. *Physical.*

The town is a fortress, surrounded by moats constantly under water. The greater rt of the town is closely built up; the streets are very narrow and winding, with one-block pavements.

### 9. *Geological.*

The subsoil is sand, loam, and bog. Houses are extensively built on timber plat-rms and piles.

## B.—MANAGEMENT OF PUBLIC WORKS.

The sewerage works entire, as well as their maintenance, including the pumping ad the disposal of the sewage on the farm, are under a thirty-year contract. They re under the supervision of an executive municipal body, with a consulting and in-pecting engineer.

## C.—DESIGN AND CONSTRUCTION OF SEWERAGE WORKS.

### 1. GENERAL SYSTEM AND ALIGNMENT.

Combined water-carriage system, with disposal on sewage farms. The town is aturally divided into three main drainage areas, the Niederstadt, a low and flat dis-rict to the southeast, the Altstadt in the north, and the Rechstadt in the southwest. ach one has a main collecting sewer, traversing the district and delivering the sew-ge at a pumping-station situated on an island in the river Mottlau. The two arms this river and the Radaune are crossed by inverted siphons, 27 inches and 18 inches n diameter. The main sewer of the Altstadt also drains the Aussenwerke suburbs ast of the town, with which it is connected by an 18-inch siphon under the moat. rom the pump, the delivery pipe—of iron and 22½ inches in diameter—takes a ortheasterly direction to the farms, crossing a branch of the Mottlau, the moat, and he river Vistula by inverted siphons.

The Rawlinson principle of straight lines between man-holes is strictly adhered to. he sewers are laid in the center of the very narrow streets.

The works were designed by Messrs. Wiebe and Latham in 1869, and finished in 871.

### II. IN STREETS, ETC.

### 1. *Shape and size of sewers.*

The sewers are all pipes, excepting the main collectors or intercepting sewers, hich are of brick, and egg-shaped.

Sizes were proportioned to carry off a quantity of rain-water equivalent to ¼ inch twenty-four hours, with a great number of overflows into the various water-chan-els intersecting and surrounding the city. The pipe sewers are mostly 9 inches; e minimum size is 6 inches; the maximum, 18 inches. The egg-shaped main sew-s are 4 feet by 2 feet 8 inches.

### 2. *Depth and grades.*

The ordinary depth of the sewers is 10 feet below the pavement, although reaching minimum of 7 feet. The depth of the intercepting sewers is 9 feet to 20 feet. The rades are as follows:

The main collectors in the Alt and Rechtstadt are 1:1,500.

The main collectors in the Niederstadt are 1:2,400.

The pipe sewers generally range from 1:100 to 1:200; in the Niederstadt, 1:360 to : 600.

The minimum grade for house branches is 1:50.

### 3. *Junctions, connections, overflows, and outfalls.*

The junctions are all made in man-holes. The house connections are provided for y branch pipes, inserted when the sewers were built. The several rivers and their branches, which intersect the city, allow much of the rain-water to run off on the surface. Yet, for the quantity which gets into the sewers, there are 10 overflows provided at different points. They discharge below mean water, and have hanging flaps to prevent the influx of river water during high stages.

The sewage is all collected on the "Kämpe," an island in the Mottlau, and there is lifted to the irrigation fields from a level of 7.2 feet below mean water. The final outfall is at an elevation of 18¼ feet above mean water.

### 4. *Ventilation.*

The sewers are ventilated by 310 man holes and 118 ventilators in the street. Both were originally provided with arrangements for passing air over charcoal, which now have been abandoned, except at a few points. All soil-pipes act as ventilators to the system; their upper ends, however, are only 2 inches in diameter, reduced from 4 inches. Rain-water conductors are trapped.

To further facilitate ventilation, the grade of the sewer is broken at the manholes, by which it was expected that the air would rise and escape more readily through them.

### 5. *Manholes, lamp-holes, flushing-shafts.*

Manholes are placed at street crossings, and can be used as flushing-shafts, in being provided with flaps for the entering and discharging pipes, and a chain to open them from the top. The manholes are placed directly over the sewers, and are covered with an iron grating, into which wooden blocks are set to deaden the noise of passing vehicles. An extra fall of a few inches is given to the sewage in most of the manholes, and in most cases their bottom forms a shallow catch-pit. The lamp-holes are pipe-shafts, 6 inches and 9 inches in diameter, and have a catch-pit and ventilating-grate at the top.

### 6. *Gullies.*

Gullies are placed in the gutters, mostly at street intersections, and otherwise are 200 feet apart. They are covered with a removable grating, 10 inches by 14 inches, and are themselves rectangular, 18 inches by 24 inches, with slightly covered sides. They have a silt-basin, 5 feet 9 inches below the surface, and a trap formed by the 6-inch outlet pipe, which first takes an upward direction after leaving the basin, at a height of 4 feet below the surface.

### 7. *Pumping station.*

The pumping station is situated on an island, "the Kämpe," in the Mottlau, to which the sewage is brought by siphons. There are two engines of 60 horse-power, each working one pump. At ordinary times one engine is sufficient, and is in action 14 to 18 hours a day. During heavy rains both operate without stopping. The daily quantity pumped in the first case is 2,641,000 to 2,905,000 gallons; in the latter 3,962.000 to 4,490,000 gallons. The amount of coal consumed is .9 1pounds per 1,000 gallons.

### 8. *Miscellaneous.*

From the numerous water-ways which the sewage crosses, many inverted siphons were necessary; from the Aussenwerke to the Altstadt, 18 inches in diameter; under the Radaune, 20 inches in diameter; under the two branches of the Mottlau, 18 and 27 inches in diameter. The pumping main from the station to the outfall also crosses the moat and the Vistula with inverted siphons 22¼ inches in diameter. They are of wrought iron, and lie about 15 to 18 feet under mean water. Before the sewage enters a siphon it passes through a horizontal screen, which retains all floating matter, and then over a catch-pit, where all heavier particles subside.

### 9. *Materials and construction.*

The intercepting and main sewers are built of brick, the branch sewers of vitrified pipe, the inverted siphons of cast and wrought iron.

The storm-water overflow pipes along the river are cast-iron pipes, 20 inches to 30 inches diameter and ¾ inch thick. The main sewers are built of two concentric courses of brick, 9 inches thick. The foundation is concrete, 9 inches below and 12 inches on each side of the brick-work. The concrete often rests on a timber platform. Pipe sewers were also often laid on plank foundations where the soil was soft. Socket-pipes only are used.

Manholes are built on concrete foundations, 12 inches deep; but they are sometimes built entirely of concrete. Gullies are constructed of concrete altogether, with wrought-iron bands placed in it to tie the whole together.

The construction of the sewers has lowered the subsoil water from 4 feet below the surface to nearly the present bottom of the sewers. New works, when necessary, are built under a general contract for a long term of years. The city removes all old drainage works in both streets and houses, in case new ones are to be built instead.

### 10. *Statistics.*

| | Yards. |
|---|---|
| Length of brick sewers (mains) | 4,593 |
| Length of pipe-sewers | 40,464 |
| Length of inverted siphons | 361 |
| Length of pumping-main to farm | 3,467 |

Outlet of pressure-pipe at farm, 18 feet 6 inches above mean water.

Siphon under Vistula, 154 yards long and 18 feet 6 inches below mean water.

For the main (brick) sewers there are 45 manholes with side entrances, 18 ventilating-shafts, 10 main overflows.

For the entire system there are 310 manholes, 118 ventilators, 420 gullies.

The total retaining capacity of the sewers is about 800 cubic yards.

## III. IN HOUSES.

Sewer connection is compulsory. All excrements and waste water must be discharged into them. The branch pipe up to the house line is built by the city at the owner's expense, and is thereafter repaired and maintained by it.

The arrangement of the pipes inside of the house is left to the owner, but it is subject to certain regulations and to the approval and inspection of the city. Detailed plans must be submitted, which, if necessary, will be corrected and altered, and the execution may also be regulated by the city if necessary.

No changes are allowed from approved plans. Every owner is required to flush all pipes in his house, so that stoppages do not occur. The city reserves the right to examine at any time any part of the house drainage and to demand the removal of any defects or such reconstruction as may be necessary. Every inlet must be trapped. Rain-water pipes are not always connected with the sewer or house drainage. The main house-pipes are 6 inches in diameter, with a grade of 1:50. Number of water-closets, 12,600.

## IV. DISPOSAL OF SEWAGE.

The sewage is all pumped to an irrigation farm near the shore of the Baltic Sea, between the mouth of the Vistula and the village Heubude, about 3 miles northeast of Dantzic. The area is about 1,260 acres, of which about 450 acres are at present irrigated.

The soil is little better than beach sand. The surface was very undulating and had to be entirely worked over. The iron pumping-main discharges into an open channel of framed timber, 12 to 20 feet above the lowest points, in which the sewage is carried at a fall of 1:2000 toward the shore. From this channel the sewage is tapped on both sides by wooden carriers, 20 inches by 24 inches, in which the sewage is carried over the fields at right angles to the main channel. The area is subdrained, the tiles running parallel to the carriers, and discharging into a collecting channel excavated through the fields for the purpose.

The effluent is clear, without taste or smell, except where passing over a reddish sand common in most parts of the area.

The irrigation is partially broad and partially in furrows. There are no winter basins, as in Berlin, the sewage being passed over the surface in the same manner as in summer.

Grass is not much raised, as there is no demand for it, and hay does not permit the use of much sewage. Beets, corn, tobacco, garden vegetables, and seed culture are considered most profitable. The sewage is distributed by two men. There are 8 attendants altogether for the farm. The temperature of the sewage in summer is about 51°.7 when reaching the fields; in winter it lowers to about 38°, and a thin ice crust is formed on the surface, after entering the open channels and the fields, below which the sewage runs as usual. The mean annual temperature of the sewage is 45°.3. The sanitary condition of the farm has always been good. Irrigation was commenced in 1872 with 19 acres. It was the first trial on the continent.

## D.—MAINTENANCE OF SEWERAGE WORKS.

### 1. *Appliances.*

The sewers are cleaned mainly by flushing. Pen-stocks, gates, and flap-valves for this purpose are numerous. Every man-hole is provided with the latter.

### 2. *Method.*

The flushing is very carefully attended to by a gang of six men, who make the entire round in twenty days. It is very efficient, so that rarely other methods are necessary, as cleaning by hand, or by drawing disks through the pipes.

A special pipe, 6 inches diameter and 7,300 feet long, is led around the southeastern part of the city, and supplied with water from the Radaune Creek, and which is solely used for flushing. It passes the heads of all the branch sewers in the Alt and Niederstadt, and its contents can be turned through any of them. Other sewers, those which are lower than the rivers, are flushed with water drawn directly from them. In addition, some sewers are flushed with the water from public hydrants. The sewers are connected whenever possible with each other, so as to use the stored-up sewage of one to flush another. There are seven pen-stocks in the brick sewers and twenty-six valves along the flushing pipe from the Radaune.

## E.—COST OF SEWERAGE WORKS.

### 1.—*Management and maintenance.*

The maintenance is under a contract for thirty years. Contractor receives free use of all ground needed for irrigation and the income from the farm, in return for pumping the sewage and keeping the sewerage works clean and in repair.

There is no assessment on properties for using sewers.

### 2 *Construction.*

Cost of sewarage works complete, about $500,000. Cost of preparing fields for irrigation, about $75 per acre.

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# BRIGHTON.

## A.—STATISTICS OF LOCALITY.

1. *Population*, 1880, in sewerage district, 108,000.
2. *Area* affecting sewerage works, nearly forty square miles. Area of town and area sewered, about 2,000 acres.
3. *Number of dwellings*, about 20,000.
4. Water supply, from chalk wells, 3,000,000 gallons. Daily average 27.8 gallons per head.
5. *Mortality*, 21.2.

### 6. *Meteorological.*

| | | Fahr. |
|---|---|---|
| 1878, mean temperature | | 50.2 |
| Highest temperature | | 81. |
| Lowest temperature | | 21. |
| Mean of all daily maximums | | 56.2 |
| Mean of all daily minimums | | 44.2 |
| Mean humidity | | 81. |
| Rainfall, annual | inches | 30 |

1876, June 22, 1 inch fell in 90 minutes during high water, or 0.011 inch per minute.

### 7. *Topographical.*

Situate on the south coast of England. The surface of the greater part of the town slopes gradually toward the beach; the other parts are very undulating and hilly, reaching elevations of several hundred feet. A few small creeks, now turned into sewers, pass through the town. The beach road is above the highest tides. Tides range ordinarily within 15 feet, the greatest range is 22 feet, the least 9 feet.

### 8. *Physical.*

The surface is closely built up in the center, but is open toward the east and west with parks, gardens, &c. The roads are all macadamized. The area around the town is mostly meadow land and but little is under cultivation. There are sixty-five miles of streets.

### 9. *Geological.*

Chalk underlies the whole town and crops out in the east, north, and high-lying districts. Westward and in the valleys it is overlaid with strata of fine sand on the chalk, followed by a layer of bowlders in the east and crushed flints in the west end of the town. Above this is chalky *débris* (coombe-rock), and at some points a stratum of clay.

## B.—MANAGEMENT OF PUBLIC WORKS.

All public works are in charge of a borough engineer, with six assistants. For maintenance of the ordinary sewers there are one inspector and four men; for the intercepting and outlet sewer there are one inspector and nine men. The sewers are cleaned once a month.

## C.—DESIGNS AND CONSTRUCTION OF SEWERAGE WORKS.

### I. GENERAL SYSTEM AND ALIGNMENT.

Combined water-carriage system. The sewage is intercepted and discharged into the sea. It is brought to the beach by sewers following the natural depressions of the surface. Along the beach it is intercepted by a sewer beginning at the west end of the town and following the shore eastwardly for a distance of over seven miles to Portobello, where it discharges by gravity. The straight-line principle is followed for the pipe sewers. The intercepting sewer was built from 1871 to 1874. Before it was finished the old valley-line sewers were carried out into the sea beyond low water; yet floating substances returned to the shore.

### II. IN STREETS, ETC.

#### 1. *Shape and size of sewers.*

Pipe sewers are used from 12 to 18 inches diameter. Brick sewers have an elliptical shape, except the main intercepter, which is circular. The ordinary section is made of three circles; the radii for the arch and invert are alike, 9 inches, and the sides are flat, their radius varying with the size. The minimum size of pipe sewers is 12 inches diameter; but brick sewers that can be entered, are preferred on account of the great amount of sand and rock silt getting into them, which necessitates much cleaning.

Sewers are made large enough to take a rainfall of ¼ inch per hour. The smallest brick sewers are 2 feet 8 inches by 2 feet; the general sizes are 4 feet by 2 feet and 5 feet 6 inches by 2 feet 6 inches. The main intercepting sewer is 5 feet diameter at its upper end and 7 feet diameter below the town.

#### 2. *Depth and grades.*

The sewers are comparatively shallow, varying from 6 to 12 feet below the surface. The grades are steep, the minimum for all but the intercepting sewer is 1:40. The maximum grade is 1:13. The grade of the intercepting sewer is 3 feet per mile (1:1760). Its upper end is 21 feet 6 inches above low water; its lower end is at low water.

#### 3. *Junctions, connections, overflows, and outfall.*

Junctions are made with easy curves in a chamber with a funnel arch. House connections are at an angle of 30°, a pipe or block being inserted opposite every house. There are three overflows from the intercepting sewer along the shore, the western (4 feet above high water at spring tides), the central (3 feet above high water at spring tides), and the eastern (2 feet 6 inches above high water at spring tides). They act from 3 to 6 times a year, and begin at the moment when the sewer is entirely filled.

The outfall for the sewage is at Portobello, 6 miles east of the town, and discharges freely at low-water of spring tides. The fall for the last mile, nearly, is only 1 foot, but the last 500 feet fall two feet, so that the average grade is preserved. At Portobello there is a pen-stock chamber with self-acting valves for shutting out the tide, and two sets of pen-stocks, one to be used when the self-acting valves are out of order, the other to pen back the sewage temporarily to flush the outfall at low water. This chamber has a tunnel passage to the beach. The platform from which to work the stocks is 3 feet 6 inches above the highest tide. Between the pen-stock and the sea the section of the sewer changes from a circle to a semi-circular arch with flat invert, and then again in an arched chamber, to three iron pipes, each 4 feet diameter, held together in a frame of timber below low water.

#### 4. *Ventilation.*

Ventilation is obtained through manholes and special shafts. Charcoal was formerly used in them, but is now abandoned. All chambers and junctions are ventilated.

The air from the intercepting sewer is drawn into a shaft 6 inches diameter and 200 feet high (100 feet above the surface of the bluff under which the sewer passes). The shaft is two miles below the town and draws the air from that distance, all openings on this stretch being carefully closed. At a point 2 miles from the shaft the velocity of the air is about 1½ to 2 feet per second. The ventilation is facilitated by a furnace placed in the shaft at the surface of the bluff, where a fire is kept constantly burning. The consumption of fuel (coke) is 36 bushels in 24 hours. The odor in the town sewers is not offensive, but in the ventilating-shaft it is very strong, therefore justifying its use.

### 5. *Manholes, lamp-holes, and flushing-shafts.*

Manholes are built with rectangular section, 3 feet by 2 feet 6 inches. They are drawn in at the top and covered with a close grating. Connected with it is a ventilating-grating, having a small catch-pit below it, and being placed to one side of the manhole, as in London. Flushing-shafts are built in the same manner. Lamp-holes are not used.

### 6. *Gullies.*

Gullies are placed in the gutters and have a horizontal grating 2 feet 3 inches by 1 foot 4 inches. They are mostly made of iron, being a simple box of the size of the grating, and 2 feet 9 inches deep. A larger size is also used, measuring 1 foot 9 inches by 3 feet 1 inch, and 3 feet 6 inches deep. Still other gullies are made of concrete, 4 feet by 2 feet in section, and 5 feet deep, having a large catch-basin, from which a 9-inch pipe, at a height of 21 inches above the bottom, leads into the sewer. These basins are not trapped. The iron gullies, however, have a trap formed by a hood covering the outlet. The depth of seal is 6 inches, the depth of the basin below the outlet is 1 foot 4 inches, the diameter of the out-let pipe 9 inches. The inlets are placed from 150 to 300 feet apart.

### 7. *Pumping stations.*

No sewage is pumped.

### 8. *Miscellaneous structures.*

To avoid steep gradients and chutes, tumbling-bays are used to let sewage drop to a lower level. They are vertical shafts with flags placed alternately on each side, and closing one-half the shaft. They slope 3 inches and are 6 feet apart. The fall is thus broken and no material lodges.

Catch-tanks are built in the main sewers just above the junction with the intercepter, to collect the road-grit from macadamized streets and heavy materials which would otherwise get into it. The tanks vary in dimensions according to the amount of material expected. The tank at the Steyne is 40 feet long, 18 feet abroad, and 18 inches deeper than the sewer. The widening checks velocity and thus causes the deposit.

### 9. *Materials and constructions.*

Sewers are built of bricks and pipes. Gault pressed bricks are used for inverts, and ordinary stock bricks for arches. Blocks, molded of 8 whole bricks and 4 halves, are used in wet ground for the bottom. Wedge-shaped bricks are not used.

Pipe-sewers are laid in a bed of hydraulic-lime mortar 3 inches deep, or cement mortar 2 inches deep. The joints are half-socket and finished in pure cement from 1 inch to 2 inches around the pipe. Many of the sewers are simply lined with a 4½-inch course of bricks, the rest being concrete, finished off at the top to a level 6 inches above the bricks. Mortar is mixed of 1 part Portland cement to 2 parts of sharp sand. Concrete has 5 parts of coarse gravel added.

Manholes, gullies, chambers, &c., are often made entirely of concrete, smoothly plastered on the inside. The manholes are drawn in at the top with several courses of brick, and the chambers are arched with a 4½-inch course of brick as a lining. Gullies are built of brick, and also made of cast iron, the material being ½ inch thick.

### 10. *Statistics.*

Length of sewers, about 55 miles. Length of intercepting sewer, 7¼ miles, of which the upper 9,900 feet are 5 feet in diameter; the next 710 feet are 6 feet in diameter; the next 27,460 feet are 7 feet in diameter; which brings it to the pen-stocks, from which it is 520 feet to the outfall.

The intercepting sewer has 24 side entrances from the beach (6 feet by 3 feet and feet 6 inches), 9 large ventilating shafts or man-holes, and 28 small ventilating shafts, inches diameter, with catch-basins at the top.

For the other sewers there are about 1,000 man-holes and flushing-shafts.

### III. IN HOUSES.

* * * * * * *

### IV. DISPOSAL OF SEWAGE.

The sewage flows to Porto Bello, 6 miles east of Brighton, and there discharges into the ocean about 100 feet from the shore.

## D.—MAINTENANCE OF SEWERAGE WORKS.

### 1. *Appliances.*

Sewers are cleaned by flushing, and the catch-tanks placed in them by hand. Penstocks are used in the large sewers, flap-valves in smaller ones. For pipe-sewers a horizontal iron plate is sometimes built into the flushing-shaft above the pipe, with an opening and stopper, which, when drawn, permits the water to drop through.

### 2. *Method.*

The town sewers are flushed with water from the city supply. The intercepting sewer is flushed below the Steyne by sea-water at spring tides, which is admitted for 4 or 5 days in succession. The upper end is flushed either by penning back the sewage, or by using fresh water twice a week when there is no rain, or by pumping sea-water.

Pipe-sewers are flushed once a month by attaching a hose to the fire-plugs, and either discharging into the sewer directly, or first into the flushing-shafts at the head of the sewer where the entire mass can be dropped at once.

The catch-tanks on the line of the sewers, especially just before discharging into the intercepting sewer, are cleaned of their silt every day or two. This and the cleaning of the gullies is mainly done at night. The sewers are cleaned once a month.

## E.—COST OF SEWERAGE WORKS.

### 1. *Management and maintenance.*

### 2. *Construction.*

| | |
|---|---|
| Cost of intercepting sewer and appurtenances, about | $500,000 00 |
| Cost per linear foot of sewer, 5 feet diameter, in open cutting | 7 00 |
| Cost per linear foot of sewer, 7 feet diameter (9-inch ring), in tunnel | 10 00 |
| Cost per linear foot of sewer, 7 feet diameter (15-inch ring), in tunnel | 12 00 |
| Cost of ventilating-shafts, per vertical foot, about | 5 00 |

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# OXFORD.

## A.—STATISTICS OF LOCALITY.

1. *Population*, 37,000.
2. *Area*, about 2,000 acres.
3. *Number of dwellings*, 7,000.
4. *Water supply.*—From subsoil water accumulating in a large excavation, up to nearly 2,000,000 gallons per day. Average consumption, 53 gallons per head per day.
5. *Mortality*, 20.4.

### 6. *Meteorological.*

| | Fahr. |
|---|---|
| Mean temperature (1878) | 49.8 |
| Highest temperature (1878) | 87.1 |
| Mean of all daily maximum (1878) | 56.6 |
| Lowest temperature (1878) | 5.6 |
| Mean of all daily minimum (1878) | 43.4 |
| Mean humidity (1878) | 82 |

Rain fell on 175 days; total annual, 27.3 inches.

Frost penetrates generally 12 inches; maximum, 2 feet.

### 7. *Topographical.*

Situate on the river Thames or Isis, where it is joined by the river Cherwell. The site of the town is low and flat, and is intersected by a canal and numerous branches of the rivers. The sewage farm is 3¼ miles southeast of the town, on high and undulating grounds.

### 8. *Physical.*

Only a small portion of the town is closely inhabited; the greater part is open, with comparatively wide streets, gardens, lawns, and open spaces. The roads, 33 miles long, are partly paved, mostly macadamized.

### 9. *Geological.*

Subsoil consists of gravel and loam, resting on "Oxford clay," which at places rises to the surface.

## B.—MANAGEMENT OF PUBLIC WORKS.

All works are in charge of a borough engineer, with necessary corps for design execution, and maintenance. House drainage must be approved by the engineers.

## C.—DESIGN AND CONSTRUCTION OF SEWERAGE WORKS.

### I. GENERAL SYSTEM OF ALIGNMENT.

Separate system. The rain-water from 1,900 acres is removed by separate channels, mostly old sewers, and discharged directly into the streams. The house sewage and the rain-water from the remaining 100 acres (roofs and back yards) is led into a new system of sewers and collected at a pumping-station 2 miles from the town, where it is raised 57 feet to a sewage farm 1¼ miles distant.

The outfall-sewer begins at the river Cherwell, where it is formed by the main sewers collecting and intercepting the sewage from the different sections of the town. Half a mile below it receives a branch draining, New Hinksey, where the water-works are located.

The town itself is divided into four drainage areas: One south of Cherwell is drained by the eastern sewer; one west of it by the northeastern; one east of the Thames is drained by the northwestern sewer, into which discharges the western sewer from Osney. All pipe-sewers, and those of brick, less than 3 feet high, are straight between man and lamp holes. The works were designed by Mr. White, borough engineer.

### II. IN STREETS, ETC.

### 1. *Shape and size of sewers.*

The rain-water sewers are mostly old and have various shapes; the newer ones are built egg-shaped. The sewers proper consist of pipes from 9 inches to 18 inches diameter, and egg-shaped sewers with the following proportions: Rad. of invert = 1; rad. of arch = 2; rad. of sides = 6; height of sewer = 6. The sizes of the rain-water channels were proportioned according to past experience and judgment. The sizes of the sewers were regulated, taking 9 inches as a mimimum in the streets, by estimating the greatest hourly flow to half fill them. (For river crossings see 8.) The outfall sewer varies from 4 feet by 2 feet 8 inches to 4 feet 6 inches by 3 feet. The other main sewers vary from 2 feet by 1 foot 4 inches to 3 feet 6 inches by 2 feet 4 inches. The pumping main is 24 inches in diameter.

### 2. *Depth and grades.*

The depth of the pipes is between 8 feet and and 12 feet below surface. The grades are arranged as much as possible to increase toward the periphery of the area. The pipe sewers have a slight drop of one or two inches at each man-hole. The grades of the branch sewers vary from from 1 in 800 to 1 in 100, the greatest number being between 1 in 500 and 1 in 200. The grade of the outfall sewer is 2.31 feet per mile, or 1 in 2,285, for 2¼ miles. The other main sewers vary from 3 feet to 13.2 feet per mile.

### 3. *Junctions, connections, overflow, outfall.*

Junctions of large brick sewers are made by easy curves in chambers with funnel arches (bell-mouths) and tongues. Junctions of pipe sewers are made entirely in man-holes, with an extra fall of an inch or two from the smaller pipes to the larger. Where mains are too deep for house connections, shafts 6 inches diameter were built at one side of the sewer at intervals of about 40 feet, the top of which forms a brick chamber, into which the house-drains discharge, the sewage descending through the shaft into the sewer. Where lateral sewers have to fall into mains many feet below them, a downward branch is put in a few feet above the junction at a descending angle of about 45° to the bottom of the man-hole. The straight pipe is in this case also continued to the man-hole to have a line of sight. When the quantity of sewage is too great for this arrangement, a flight of steps of blue bricks is built instead. An overflow for accidents is at the pumping-station. The outfall sewer is constructed sufficiently large to hold all sewage accumulating at night.

### 4. *Ventilation.*

Ventilation is had through man-holes and lamp-holes; also through soil-pipes, where not objected to by the owners. All chambers and junctions are ventilated to surface. The odor in the sewers is not strong. The rain-water channels have a slightly foul smell. At the pumping-station the odor was only disagreeable near the screens. When the sewage arrived on the farm its odor again was only slight.

### 5. *Man-holes, lamp-holes, flushing-shafts.*

The straight-line principle being strictly adhered to, man and lamp holes are placed at every change of direction, horizontal or vertical, at every junction and at every summit. They are placed over the sewers, are square in section, and covered with a circular iron grating which has openings for ventilation. From the cast-iron frames in which the grating fits, circular wrought-iron boxes are hung to catch the road detritus falling through the grating. Eight wrought-iron ladders are built into the man-holes.

At the head of every line of sewer the man-hole also serves as a flushing-shaft.

Water is laid on from the nearest main by a 1½-inch pipe and screw-down tap. At the bottom of the shaft is a cast-iron flap, which, when lowered, closes the sewer. The tap being opened, the water fills the shaft and is suddenly discharged, when the flap is raised with a chain from the top.

### 6. *Gullies,*

The gullies are placed in the gutters with a horizontal grating 14 inches by 18 inches. They are 3 feet 6 inches deep, and have a trap and catch-pit 18 inches deep below outlet-pipe.

### 7. *Pumping-station.*

The pumping-station is situated 2 miles below the town. There are two engines, each 40 horse-power, working a plunger pump. The sewage is raised 57 feet, and the length of the pumping main is 1¼ miles. There is also an auxiliary engine of 14 horse-power, with a 12-inch centrifugal pump. Average quantity of sewage pumped daily is 1,500,000 gallons. The pumps are only worked during the day, as the outfall-sewer can store 750,000 gallons during the night.

### 8. *Miscellaneous structures.*

The smaller brick sewers have resting-places, 6 feet high, at certain points, to admit of an upright position. They are specially ventilated. The pumping main is supplied with self-acting air-valves.

### 9. *Materials and construction.*

The sewers are built of brick and of vitrified pipes. The brick sewers were built with great care and with concentric rings to prevent infiltration of subsoil-water.

Sizes up to 2 feet 6 inches by 1 foot 8 inches in dry ground have one course of brick laid into a bed of concrete, which reaches to the springing line; the largest size has the concrete extending to 6 inches over the arch. In wet ground the 2 feet 3 inches by 1 foot 6 inches sewer was built of two rings, as were also all of the larger ones. The sewer in the tunnel, 3 feet 3 inches by 2 feet 2 inches, has two courses below the spring and four courses above it, the backing being concrete.

The brick-work was laid in Portland cement mortar, 1 to 1 sand; the concrete for filling spandrils was made of 1 part cement and 6 parts sharp gravel. Eight miles of sewers are laid from 1 to 11 feet below the average summer water-level in the river.

The subsoil-water is very abundant. To prevent it from entering the sewers, the ring joints were carefully rendered with cement coats ¼ inch thick, as follows:

For the outfall sewers there were 3 coats, two of 2 parts cement to 1 part sand; a third was of pure cement. The smaller sewers had but one coating. The stone-ware pipes were jointed in cement mortar, with sometimes a band of clay puddle in addition. Stanford's patent joint was used where trenches were very wet.

To get rid of the subsoil-water during the construction of brick sewers, pipes, generally 12 inches in diameter, were laid underneath the sewer to the pumps and left in permanently. The inverts, both for brick and pipe sewers, were leveled with extreme care.

Man-holes were built of brick and were covered with ventilating man-hole covers, having wooden blocks inserted. The 24-inch pumping main to the sewage farm is of cast iron, with leaded joints.

A tunnel 202 feet long was driven under the old tower of Oxford Castle, lower than the bed of the river and within 6 feet of it horizontally. A tunnel was also driven under the Great Western Railroad.

The numerous streams necessitate many crossings, six under the Isis and Cherwell, one under the canal, and several under minor streams. They are of cast iron surrounded by concrete.

Two of the river crossings are inverted siphons of iron, with vertical brick shaft on either side of the river. A fall of a few inches is given to them and the lower end has a sump. Sluices are provided for flushing and for detaining sewage in case of repairs. For the two Cherwell crossings, the headway being limited, iron tubes were put in, 1 foot 10 inches by 3 feet 9 inches wide, with segmental top and bottom, and an area of 6.25 feet. The whole was surrounded by concrete. The tube under the Isis has a modified egg shape 2 feet by 2 feet. The sewers under the canal and Trillmill stream are of brick-work, covered by cast-iron segmental pipes and surrounded with concrete 12 inches to 18 inches.

### 10. *Statistics.*

| | Miles. |
|---|---|
| Length of brick sewers | 7¼ |
| Length of pipe sewers | 25 |
| | 32¼ |

Number of man-holes and lamp-holes, over 500.

Discharging capacity of sewers, filled to springing line, is 5,000,000 gallons per day.

In wet weather about 2,000,000 gallons of surface-water gets into sewers, which, with sewage, makes about 4,000,000 gallons.

## III. IN HOUSES.

Sewer connection is not yet obligatory, although about three-quarters of all houses are already drained. There are about 7,000 water-closets. The main house pipe joins the sewer about 2 to 3 feet below cellar level.

## IV. DISPOSAL OF SEWAGE.

The sewage is delivered on a farm of 335 acres. From the point of discharge it runs partly in open carriers and iron pipes through and around the entire area, crossing some slight depressions by inverted siphons. At various points the sewage is tapped and led into earth carriers (grade 1 : 1000), which distribute it to the different fields. There are nine sections, comprising 28 acres, which have been leveled and prepared for filter-beds, and which alone could filter the entire quantity of sewage. Five are level and four are on a slope. The remaining ground is used for broad irrigation.

At four termini of the pipe carriers there are tanks, built of brick, 5 feet square, with wooden sluices, from which the sewage is turned into the open carriers. At various places there are movable weirs by which the velocity, if too great, can be reduced, or the sewage dammed up, in order to enable it to spread over the fields. The filter-beds are subdrained, and the sewage drains away freely in a clear and tasteless condition.

## D.—MAINTENANCE OF SEWERAGE WORKS.

### 1. *Appliances.*

Man-holes are used as flushing-shafts at the head of a sewer. At the bottom is a cast-iron flap, which when lowered closes the sewer. At intermediate man-holes grooves are left in the brick-work for the insertion of wooden stops, to obtain a head varying from 18 inches to 3 feet.

In the outfall and other sewers with light grades wooden pen-stocks or doors which can pond up the sewage 5 feet 6 inches high, are placed so as to slide up and down in grooves. They have rack-and-pinion gearing, with a spindle reaching to and operated from the surface of the ground. The man-holes have dirt-boxes hanging under the cover to catch the droppings.

### 2. *Method.*

The smaller sewers are flushed by water from the city supply. It is laid on from the nearest main by a 1½-inch pipe, and when having filled the flushing-shaft or man-hole is suddenly released on raising the flap by a chain from the top. A good scour is the result. The larger sewers are flushed by sewage dammed up for the purpose by pen-stocks. The latter are also used for laying the sewers partially dry, section by section, for a few hours at a time, to facilitate inspection. By this means the sewers are kept in a very good condition.

The dirt-boxes hanging from the man-holes and gullies which connect with the rain-water sewers, as well as the latter themselves, are cleaned frequently.

## E.—COST OF SEWERAGE WORKS.

### 1. *Management and maintenance.*

* * * * * * *

### 2. *Construction.*

Cost of subdraining sewage farm, $87 per acre; cost of land for farm, $456 per acre; cost of total preparation for irrigation, $171 per acre.

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# AMSTERDAM.

## A.—STATISTICS OF LOCALITY.

1. *Population*, 1880, 304,000; population using Liernur system, 27,600.
2. *Area*, 1,606 acres.
3. *Number of dwellings*, 32,000.
4. *Water supply*, 10,000 cubic meters daily, obtained from the Harlem dunes. Per day per head, 8.44 gallons.
5. *Mortality*, mean for 10 years, 24.8; in 1878, 24.4.

### 6. *Meteorological.*

* * * * * * *

### 7. *Topographical.*

Situated on an arm of the Zuyder Sea at the mouth of the Amstel, a small river passing through the city in several arms. The city is, in addition, intersected by numerous canals, dividing it into 90 islands. It is almost on a level and only slightly above high tide.

### 8. *Physical.*

The city, from the numerous canals in all directions, is rather open. A few of the central districts are, however, very crowded. The streets are all paved. They are narrow in the central parts. Toward the periphery (where the Liernur system of sewerage is applied) the streets are wider and airy.

### 9. *Geological.*

The subsoil is mud, loam, and loose sand, resting on clay at a depth of 20 to 50 feet. The site was originally a peat-bog. All buildings rest on piles.

## B.—MANAGEMENT OF PUBLIC WORKS.

All public works are supervised by an alderman (échevin). The departments for design, construction, surveys, and repairs are under the guidance of a director, and are subdivided into bureaus for streets, parks, canals and sewers, buildings, &c. Water and gas are furnished by private parties. The department for city maintenance is to a certain extent independent of the former and includes the cleaning of streets, canals, and sewers (not Liernur system). The bureau of streets, parks, canals and sewers is charged with all engineering works, including the design, construction, and maintenance of the Liernur system. It is under a chief engineer, assisted by one adjunct and four principal assistants, one for streets, one for parks and public promenades, one for canals and sewers, and one for the Liernur system. In addition there are about 20 assistants. For the Liernur system there are 3 machinists and 16 men for maintenance.

## C.—DESIGN AND CONSTRUCTION OF SEWERAGE WORKS.

### I. GENERAL SYSTEM AND ALIGNMENT.

Pneumatic separate system (Liernur) for the removal of excrementitious matter of a small portion of the town. Dry removal in pails, holding 8 gallons, and exchanged daily, for the rest of the town.

Storm-water runs entirely over surface or into old sewers.

The Liernur pipes, which are of iron and into which the houses drain, unite every several hundred feet at street intersections in an air-tight reservoir, into which the sewage is drawn by means of a vacuum created in it through a pipe leading to the air-pump or central station. After the sewage from the several branches is collected in the reservoir it is again drawn by a vacuum to the central station itself, where it is run into barges and removed. Usually there is only one branch pipe for a street; occasionally there is one on each side. The main pipes from the reservoirs to the air-pump, which are not connected with the houses, are additional, which altogether makes two pipes in about one-half of all the streets.

The sewage frequently passes twice over the same block, first being drawn into the reservoir and then through another pipe back again partially through the same street to the central station. The sewage collected by the Liernur pipes is very dilute, 50 parts fluid to 1 part solid, notwithstanding that precautions are taken against the introduction of much water. Where the system is applied to single and scattered houses the pipes are emptied by pneumatic carts when in the blocks, and by a steamboat when near the canals.

The cart and boat carry a cask. A vacuum is created in it in both cases by a pump attached to the cart or on the boat, and the sewage is drawn into them. The entire system was designed by Captain Liernur, and introduced in 1871.

### II. IN STREETS, ETC.

#### 1. *Shape and size of sewers.*

The shapes of the old sewers for rain and house water vary; they are mostly circular, from 1 foot to 2½ feet in diameter. The Liernur sewage pipes are circular and all 5 inches in diameter, both branches and mains.

#### 2. *Depth and grade.*

The depth of the rain and house water sewers is about 6 feet; the depth of the Liernur pipes is very shallow, averaging 1 meter. The grades of the sewers range from 1 in 500 to 1 in 200; for house drains 1 in 50. The grades of the Liernur pipes do not affect the velocity, yet it is preferred not to make them level. The discharging mains from the reservoirs to the pumps have a fall of 1 in 800; the branch pipes leading into the reservoirs have a fall of 1 in 200 to 1 in 150.

#### 3. *Junctions, connections, overflows, and outfall.*

The junctions of the main Liernur pipes are made in iron chambers (reservoirs), cylindrical in shape, about 7 feet long and 4 feet diameter. The inlet-pipes enter near the top; the discharge-pipe also enters near the top, but is extended through the cylinder into a depression at the bottom, 4 inches deep, so that it can draw out the sewage to the greatest possible extent. The reservoir is provided with the necessary valves for inlet and outlet pipes. The house connections are at right angles and have one or more "barometrical traps" (siphon traps with a constant depth for the entire system) before entering the house. Overflows are of course not required. The outfall of each district is at the air-pump, and is situated at a canal where the sewage is turned into barges. The outfalls for those houses which are relieved by an air-pump on a boat are of course also along the canals.

### 4. *Ventilation.*

Ventilation for the Liernur system is only necessary at the pump, where the air is carried through the fire, or escapes from a high chimney. The odor is intense without either precaution.

### 5. *Man-holes, lamp-holes, and flushing-shafts.*

These structures are not required for the Liernur system. Access to the pipes is only had by breaking into them.

### 6. *Gullies.*

As no street water runs into the Liernur system, no gullies are required for it. There are very few in the town, because the rain-water runs on the surface to the numerous canals.

### 7. *Pumping-station.*

* * * * * * *

### 8. *Miscellaneous structures.*

* * * * * * *

### 9. *Materials and construction.*

The sewer pipes, chambers, and reservoirs are all made of cast iron, and carefully joined with lead joints in order to be air-tight.

### 10. *Statistics.*

Length of main pipes from reservoirs to pumps, about 3,160 yards.
Length of branch pipes, about 8,780 yards.
Number of reservoirs, about 15.
Number of independent districts for which system is used, 5.
Number of houses drained, 1,190.

## III. IN HOUSES.

In the older part of the city, cess-pools are still in use with overflows into the canals, when near them. All house and rain water runs into the canal. In the newer sections of the city both the cask and Liernur systems are used. The casks receive both solids and liquids. The pipes leading away the waste water are generally 12 inches diameter, and of terra-cotta. The pipes for the Liernur system are of iron, 5 inches in diameter, and have several traps (barometric) on the line. The soil-pipe is carried beyond the roof, and also a special ventilating-pipe for each closet. The closets are of the hopper style, and only such, of a water-saving character, are allowed. Nothing but water-closet contents get into the Liernur pipes; other matter is led over the surface or into the rain-water sewers. Each house can be disconnected from the street system, in case of repairs, by a hand-valve.

## IV. DISPOSAL OF SEWAGE.

The contents of the casks are removed to neighboring farms. The Liernur sewage is discharged into boats, by which it is taken to near farms, where it flows over some fields in a very unsystematic way, and so far without financial success. Only a slight and uncertain return is had from it. At present the sewage is often mixed with street sweepings, and in this way sells for 30 cents a cubic yard delivered, or with the contents of casks, in equal parts, when it sells for 60 cents a cubic yard delivered.

## D.—Maintenance of Sewerage Works.

### 1. *Appliances.*

There are three stationary engines and one steamboat for the Liernur service. They are alike supplied with air-pumps, receiving-tanks, &c.

### 2. *Method.*

The sewage is drawn to the receiving-tanks and conveyed away as described above. The pipes are emptied once every week-day, some also on Sundays. Flushing or other method of cleaning is not practicable nor necessary, as the process of removing sewage keeps the pipes in order. Stoppages occasionally occur, and they are usually relieved by breaking into pipes. The attendance upon the system consists of 3 machinists, 2 stokers, and 4 laborers for the 3 engines, and 1 machinist, 1 stoker, 1 captain, and 2 laborers for the steamboat. In addition, 2 persons attend to the reservoirs and valves, and operate the collection of the sewage.

In 1880 there were 7,253,602 gallons of sewage collected and removed. Daily average per person, 0.74 gallon.

## E.—Cost of Sewerage Works.

### 1. *Management and maintenance.*

*Running cost of Liernur works in* 1880.

| | Persons. | Total cost. | Cost per head per year. |
|---|---|---|---|
| Fixed stations | 21,939 | $4,773 | $0 22 |
| Steamboat service | 4,656 | 3,919 | 0 84 |
| Pneumatic carts* | 1,351 | 2,166 | 1 60 |
| Total | 27,946 | 10,858 | =0 39 |

*Not Liernur system proper.

Cost of maintenance of Liernur works up to 1877, excluding transportation of sewage in boats and utilization, 45 cents per year per head. Cost of maintenance of cask system, 73 cents per year per head. Return from sale of Liernur sewage in 1877, $522.

In 1880 it was not salable unless prepared, as follows: When mixed with contents of casks in equal parts it sold for 60 cents per cubic yard delivered. When mixed with street sweepings it sold for 30 cents per cubic yard delivered.

Assessment for system: City paid for the pipes up to 20 inches from house line; owners paid the rest. The latter pay an annual rent of $3.25 for connection, also 12 cents per hour of labor necessary to remove obstructions in the house-pipes.

### 2. *Cost of sewerage works.*

The Liernur works entire have cost $124,500; the Liernur house-fittings, $70 to $90, including pipes, per dwelling.

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# APPENDIX No. 2.

## MAXIMUM RAINFALLS.

| Place. | Date. | Total fall. | Length of storm. | Fall per minute. | Author. |
|---|---|---|---|---|---|
| | | *Inches.* | *Min.* | *Inches.* | |
| London | Aug. —, 1846 | 3.3 | 140 | 0.024 | ........ |
| | Aug. —, 1846 | 2.0 | 30 | 0.067 | ........ |
| | July —, 1852 | 0.5 | 15 | 0.033 | ........ |
| | Oct. —, 1857 | 2.92 | 2,160 | 0.0013 | (2) |
| | June —, 1874 | 0.96 | 30 | 0.032 | ........ |
| | June 23, 1878 | 3.0 | 90 | 0.033 | ........ |
| | July 14, 1880 | *0.36 | 12 | 0.930 | ........ |
| | (?) | 6.0 | 90 | 0.067 | (6) |

MAXIMUM RAINFALLS—Continued.

| Place. | Date. | Total fall. | Length of storm. | Fall per minute. | Author. |
|---|---|---|---|---|---|
| Paris | July 16, 1860 | 1.496 | 20 | 0.0740 | ........ |
|  | May 23, 1865 | 1.024 | 20 | 0.0512 | ........ |
|  | July 16, 1866 | 1.260 | 30 | 0.0420 | ........ |
|  | Sept. 20, 1867 | 1.614 | 20 | 0.0807 | ........ |
|  | May 22, 1870 | 1.024 | 60 | 0.0171 | ........ |
|  | July 27, 1872 | 1.575 | 60 | 0.0262 | ........ |
|  | Aug. 15, 1879 | 0.642 | 40 | 0.0160 | ........ |
| Berlin | July 11, 1858 | 2.560 | 840 | 0.0030 | ........ |
|  | (?) | 0.787 | 20 | 0.0393 | ........ |
| Vienna | June 23, 1853 | 0.8819 | 60 | 0.0150 | ........ |
|  | July 19, 1854 | 0.843 | 60 | 0.0140 | ........ |
|  | May 2, 1860 | 1.025 | 110 | 0.0175 | ........ |
|  | July 18, 1870 | 1.598 | 140 | 0.0114 | ........ |
| Hamburgh | (?) | 0.827 | 45 | 0.0184 | ........ |
| Frankfort | July 6, 1873 | 1.201 | 60 | 0.0201 |  |
|  | July 4, 1875 | 1.575 | 100 | 0.0154 |  |
|  | April 2, 1876 | 0.709 | 40 | 0.0177 |  |
| Liverpool | Greatest observed rainfall, 1878. | 0.750 | 60 | 0.0125 |  |
| Brighton | June 22, 1876 | 1.00 | 90 | 0.011 |  |
| Kiel | Aug. 4, 1879 | 1.457 | 10 | 0.1454 |  |
|  | Oct. 3, 1879 | 0.929 | 20 | 0.0465 |  |
| Brussels | June 4, 1839 | 3.3859 | 180 | 0.0188 |  |
|  |  | 4.2718 | 540 | 0.0079 |  |
| Clausthal | June 11, 1858 | 4.130 | 1,080 | 0.0038 | (1) |
|  | Dec. 16, 1854 | 2.225 | 780 | 0.0028 | (1) |
| Brocken | July 31, 1858 | 4.961 | *1,440 | 0.0035 | (1) |
| Güterslohe | July 19, 1852 | 3.556 | *720 | 0.0049 | (1) |
| Dresden | June 9, 1862 | 0.851 | 20 | 0.0475 | (1) |
| Posen | July 26, 1863 | 0.949 | 20 | 0.0425 | (1) |
| Königsberg | July 13, 1878 | 1.59 | 135 | 0.012 | Wiebe. |
|  | Aug. 17, 1878 | 2.43 | *720 | 0.0034 | Wiebe. |
| Zechen | May 13, 1858 | 1.744 | 60 | 0.029 | (1) |
| Breslau | Aug. 6, 1858 | 3.740 | 120 | 0.0312 | (1) |
| Genf | May 20, 1827 | 6.394 | 180 | 0.0355 | (1) |
| Salzwedel | Aug. 18, 1862 | 3.071 | 165 | 0.0186 | (2) |
| Verviers | Sept. 26, 1801 | 14.071 | 1,080 | 0.0130 | (1) |
| Montpelier | (?) | 5.118 | 360 | 0.0213 | (2) |
| Togense | Oct. 9, 1827 | 31.072 | (?) | (?) |  |
| Marseilles | Sept. 21, 1838 | 1.574 | 25 | 0.063 | (2) |
|  | (?) | 13.0 | 840 | 0.0155 | (6) |
| **Geneva** | May 30, 1827 | 6.378 | 180 | 0.0352 | (4) |
|  | (?) | 6.0 | 180 | 0.0333 | (6) |
| **Genoa** | Oct. 25, 1822 | 31.976 | 1,440 | 0.0222 | (1) |
|  | (?) | 32.0 | 1,440 | 0.0222 | (6) |
| **Budapest** | (?) | 2.55 | 60 | 0.043 | (7) |
| **Munich** | (?) | 2.0 | 30 | 0.067 | (7) |
| **Switzerland** | (?) | 2.0 | 30 | 0.067 | (7) |
|  | (?) | 0.875 | 10 | 0.087 | (7) |
| **Catskill, Hudson** | July 26, 1819 | 17.993 | 450 | 0.040 | (5) |
| **Havana** | July 18, 1854 | 2.815 | 150 | 0.0187 | (2) |
| **Cayenne** | (?) | 11.024 | 600 | 0.0184 | (2) |
| **Washington** | (?) | 2.0 | 40 | 0.050 |  |
| **Philadelphia** | July —, 1842 | 6.0 | 120 | 0.050 | (6) |
| **Norristown, Pa** | (?) 1865 | 9.0 | 300 | 0.030 | (6) |

* Nearly.

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## DEDUCTIONS.

Largest quantities of rainfall occur in the summer, and usually extend over large areas. Variations of quantity increase with the elevation above the sea. Rainfalls in or near elevated regions are generally greater than in low and flat regions. More rainfalls occur in warm than in cold countries.

## APPENDIX No. 3.

## CATALOGUE OF PUBLICATIONS RELATING TO SEWERAGE.

COMPILED BY RUDOLPH HERING, C. E.

### I.—ENGLISH LANGUAGE.

CLASS A.—*Books and pamphlets, including articles from periodicals published separately in book form. Classified according to authors and in a few instances to places and subjects.*

ADAMS, J. W.—Sewers and drains for populous districts. 8vo., 228 pp. New York, 1880. $2.50.
——— *See* CLASS B. BROOKLYN.
AMERICAN PUBLIC HEALTH ASSOCIATION.—Proceedings of the ———.
AUSTIN, HENRY.—A few points in relation to the drainage of towns. "Transactions of the National Association for the Promotion of Social Science." 1857, p. 422-429.
——— *See* CLASS B. CROYDON, UTILIZATION OF SEWAGE.
BANNER.—Wholesome houses.
BARDWELL.—A brief account of Mr. Bardwell's improved method of utilizing sewage and urine, and for facilitating their passage through pipes to prevent the pollution of rivers and streams. 6*d.*
——— Twelve reasons against sewage irrigation. 3*d.*
BARRY, T. D.—Present state of the sewage question. 8vo., 18 pp. Liverpool, 1870. 1*s.*
BAYLES, J. C.—House drainage and water service in cities, villages, and rural neighborhoods. Roy. 8vo., 350 pp. New York, 1878. $3.
BAZALGETTE, J. W.—Lecture on the main drainage of the metropolis. 8vo., 41 pp. 1857.
——— Main drainage of London. Proceedings of the Institute of Civil Engineers. 8vo., 92 pp. London, 1865.
——— West metropolitan main drainage works. "Engineer," 1873, vol. 36, pp. 95-99-102-136-169-256.
——— The sewage question. Proceedings of the Institute of Civil Engineers. 8vo., 192 pp. London, 1877.
——— *See* CLASS B. CAMBRIDGE, METROPOLITAN M. D.
BELL, R.—Objections to Bazalgette's scheme for the drainage of the metropolis. 8vo. London, 1856.
BIRCH.—Disposal of town sewage. 8vo., 36 pp. London, 1870. $0.50.
BIRCH, R. W. P.—Sewage irrigation by farmers, or fifty instances of profitable sewage utilization. 8vo. London, 1878. 2*s.* 6*d.*
BIRD, P. H.—Hints on drains, traps, closets, sewer-gas, and sewage disposal. 8vo. London, 187-. 2*s.* 6*d.*
——— Ventilation of house-drains, soil-pipes, and sewers.
BIRMINGHAM.—The sewage of ———. "Engineer," vol. 32; 1871; No. I, p. 329; No. II, p. 355.
BLAKE.—Sewage-poisoning. How to avoid it in the cheapest and best way.
BOULNOIS, H. P.—Sewer ventilation. Improved system for disposal of noxious gases from sewers. 8vo., 16 pp. Exeter, 1880. 6*d.*
BROOM, G. C.—Wolverhampton sewerage scheme, and hints on the ventilation of house drainage. 8vo., 50 pp. London, 1878. 1*s.* 6*d.*
BUCHAN, W. P.—A text-book to the practice of plumbing and house drainage. (Weale's series.) 12mo., 232 pp. 300 illustrations. London, 1880. 3*s.* 6*d.*
BUCK.—Treatise on hygiene and public health. 2 vols., 8vo. New York, 1879.
BUCKHURST, HILL.—Sewage, utilization of ———. "Engineer," 1872, vol. 34, p. 207.
BURKE, W. RALPH.—A hand-book of sewage utilization. 8vo., 60 pp. London, second edition, 1873. 3*s.* 6*d.*
BURN, SCOTT.—Utilization of sewage, irrigation and reclamation of waste land. 2*s.* 6*d.*
CARPENTER, Dr. A.—Preventive medicine and public health. Lectures on Beddington sewage farm, &c. 12mo., 367 pp. London, 1877.
——— *See* CLASS B. CROYDON.
CHATTERTON. *See* GOWER. IN CLASS B, *see* CAMBRIDGE.
CHAUMONT. Healthy habitations.
CHESBROUGH, E. S.—Sewerage; its advantages and disadvantages, construction, and maintenance. From eighth annual report of the State board of health of Massachusetts. 8vo. Boston, 1877.
——— *See* CLASS B. BROOKLINE, CHICAGO, NEW HAVEN.
CHILD, Dr. GILBERT W.—The present state of the town sewage question. 8vo., 34 pp. Oxford, 1865.

**Clarke**, E. C.—Common defects in house drains. 8vo., 24 pp. Boston. Extract from State board of health reports, 1879.

**Concrete.**—Bournemouth drainage. Vindication of the rock-concrete tubes. 8vo. London, 1879. 1*s*.

**Copeland**, **James**.—Drainage and sewerage of London and large towns; their evils and cures. 12mo., 35 pp. London, 1857.

**Corfield**, W. H.—Digest of facts relating to the treatment and utilization of sewage. 8vo., 343 pp. London, 1871. 10*s*.

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**Danchell**, F. H.—Concerning sewage and its economical disposal. 8vo., 40 pp. London, 1872. 1*s*.

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——— Sewage the fertilizer of land, and land the purifier of sewage. 1871.

——— Intermittent downward filtration and irrigation. 1873.

——— Sanitary science applied to towns and rural districts, 1874.

——— Sanitary engineering. Roy. 8vo., 429 pp. London, 1877. £1 5*s*.

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——— Intermittent downward filtration, *per se*, and in combination with surface irrigation. 8vo., 30 pp. London, 1880. 1*s*.

——— Ten years' experience in intermittent downward filtration. 8vo., 78 pp. London, 1880.

——— Sanitary works and sewage utilization. 8vo. London. 1*s*.

——— The sewage question. 8vo.

——— Under-drainage of land, its development and maintenance. 8vo.

**Donaldson**, **Geo.**—Drainage of the town of Richmond, Surrey. Proceedings of the Institute of Civil Engineers. 8vo., 17 pp. London, 1856.

**Downes.**—How to avoid typhoid fever and allied diseases. Plain rules on house drainage.

**Drainage.**—A scheme for the effectual drainage of towns, with projects of important natural measures which may be ingrafted upon it. 8vo., 42 pp. Plates. London, 1855.

**Drysdale and Haywood.**—Health and comfort in house-building. 8vo., 129 pp. London, 1876.

**Dyke**, T. J.—Downward intermittent filtration of sewage at Merthyr Tydvil.

**Eassie**, **Wm.**—Healthy houses. 12mo., 230 pp. New York, 1876. $1.

——— Sanitary arrangements for dwellings.

**Ewart.**—*See* **Class** B. **Oxford.**

**F. C.**—Plan for collecting sewage in London and other towns, and removing it to the country. 1858. 6*d*.

**Fanning**, **John** T.—A practical treatise on water supply engineering in North America. With numerous tables. 8vo., 620 pp. New York, 1878. $6.

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SHEDD.—*See* CLASS B. HOLYOKE, LYNN, PROVIDENCE, TAUNTON.

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SLAGG, C.—The principle of town drainage. Royal 8vo. London, 1868.

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*β*. Direction générale des eaux et des égouts de Paris.

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# APPENDIX 5.

## *THE RELATION OF SOILS TO HEALTH.*

### A PRELIMINARY REPORT TO THE NATIONAL BOARD OF HEALTH.

### FILTERING CAPACITY OF SOILS.

By Raphael Pumpelly, assisted by George A. Smyth, Ph. D.

Newport, R. I., *March* 28, 1881.

My Dear Sir: About a year ago I had the honor of addressing a letter to you requesting the aid of the National Board of Health in carrying on a series of investigations into the relations of different soils to the air and water currents passing through them. My object was to aid in establishing upon an exact basis the practically important department of sanitary geology.

The immediate subjects to be studied in soils of different compositions and structure were:

1. The rates of flow of water and of air under given conditions.
2. The capacities of soils as filters in eliminating organic and inorganic substances from liquids.
3. Their capacities as filters in eliminating the living low forms of vegetable life, both germs and adult organisms, from ground-water and ground-air.

The National Board of Health very liberally enabled me to undertake this work by agreeing to pay the salary of a chemical assistant and the necessary expenses.

I was fortunate in being able to associate with myself Prof. George A. Smyth, to whose skillful and delicate manipulation the successful issue of our joint work is largely due.

It is proper that I should state here that although the methods of attacking the above-mentioned problems, and the invention of the apparatus were the result of frequent consultations between us, the actual laboratory work has been wholly performed by Prof. Smyth.

Although it was my intention that the proposed investigations should be conducted as far as possible in the ground itself, upon undisturbed soils, it was necessary to first study in the laboratory the behavior, in their pure state, of the separate constituents of soils, quartz, sand, clay, loam, marl, loess, &c.

Yours, respectfully,

RAPHAEL PUMPELLY.

To the President *National Board of Health,*
*Washington, D. C.*

### GENERAL RESULTS.

Thus far the work has been confined to the soils and some other substances as filters in eliminating living low vegetal organisms from air and fluids, and in this direction we have only made a beginning.

The great practical importance of this part of the subject led to its being considered first. The weight of authority among students in sanitary science is in favor o- recognizing some genetic relation between the lower vegetal organisms and the epif demic prevalence of certain diseases. It is known that these low forms of life are capable of being carried in fluids and of floating in the air where, owing to their almost infinitesimal lightness, they are buoyed up by the slightest currents.

It has long been known that certain soils in time lose their ability to filter out the impurities from polluted waters. Many cases of disease are supposed to have been traced directly to the use of water containing sewage that had passed for a greater or less distance through the soil.

Again, it is an established fact that the air with which the soils are permeated above the surface of the ground-water vibrates to every barometric change in the outer atmosphere; that it moves in currents caused by this sympathy and by thermometric differences. And Pettenkofer and others have called attention to the importance of these currents of ground-air from a sanitary point of view.

When we consider that every vault, cesspool, and cemetery is a center of pollution to the ground-water which supplies our wells, and, to a certain extent, also the reservoirs for cities, we can appreciate the importance of ascertaining to what extent soils are capable of eliminating the injurious properties contributed by the pollution.

Through the cellars our houses become, especially in winter, the ventilating chimneys for the surrounding ground; sucking in from all directions the air that has been nearly stagnant in the pores of the soil during the summer. In view of the fact that the ground-air is polluted by vaults, cesspools, and cemeteries in the country, and by the garbage of made ground and defective drains and sewers in the cities, it is important that we should determine the extent to which different soils are able to filter the injurious properties out of the air passing through them.

In working toward the solution of these problems, our apparatus has consisted essentially of two parts:

1. The substance to be tested as a filter.
2. An infusion of beef, or some other easily putrescible substance.

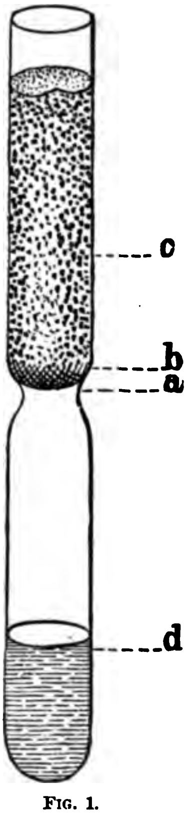

FIG. 1.

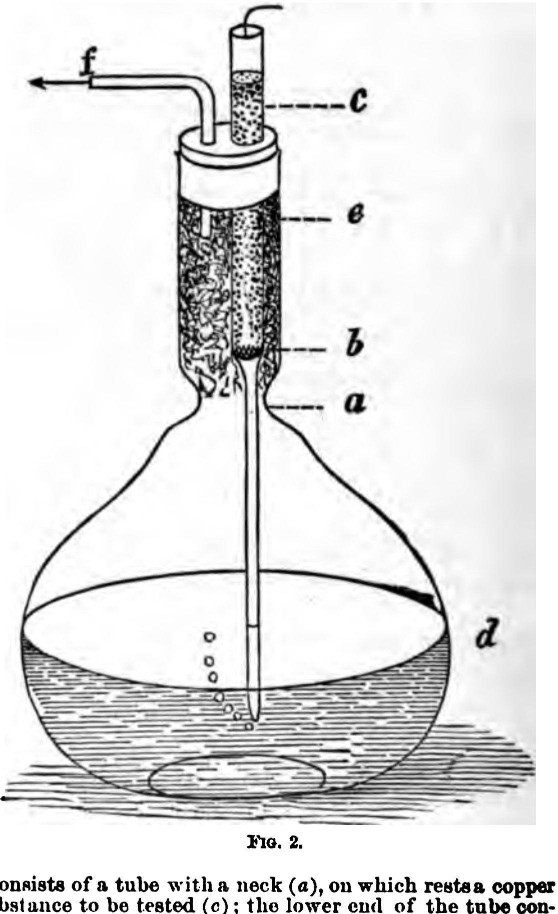

FIG. 2.

In the simplest form this consists of a tube with a neck (*a*), on which rests a copper gauze (*b*) supporting the substance to be tested (*c*); the lower end of the tube contains the infusion (*d*). The whole apparatus is heated sufficiently to insure the destruction of any germs or adult bacteria. Similar infusions exposed in open capsules unprotected to the air invariably showed signs of putrefaction within forty-eight hours. Such exposures accompanied all of our experiments as control tests.

The experiments conducted thus far fall readily into four classes.

**Y FILTERS FOR AIR.**—The sterilized infusion was protected from the germs
faction that float in the air, only by the column (1 millimeter to 17 centimeters
the substance to be tested.
s series there were nearly ninety filters tried of asbestus, sand, loess, charcoal,
harcoal, and coal ashes. After standing three to eight months, omitting
ective and one doubtful case, the infusions used are *all* sound, excepting
he filter was coarse sand (10°-20°, *i. e.*, 10 to 20 grains to an inch), or animal
that would just pass through a sieve of 15 meshes to the inch.
**ET FILTERS FOR AIR.**—These differed from the first only in having the filters
d with sterilized water. The same materials, except coal ashes, were used
e dry filters, and, disregarding
btful and five defective cases,
proved perfect protectors to
sion beneath them, except two
coarse animal charcoal (15°),
of loosely-packed asbestus,
ailed to protect the infusions,
owing to absorption of the
nd conversion into dry filters.
**QUANTITATIVE EXPERIMENTS WITH DRY FILTERS OF SAND,
S, AND ANIMAL AND VEGETA-
RCOAL.**—Fig. 2 shows the ap-
employed.
ese experiments an artificial
was produced, the air being
by an aspirator connected at *f*
. 2) through the filter (*c*) and
infusion (*d*).
set of these experiments the
passed through in a slow cur-
to 6 liters in 24 hours. These
ents were started at different
tween June 10 and October 30,
jected to continuous currents.
er, loosely-packed asbestus, 5
ters high, has failed after pass-
liters of air. It will be seen
tables that the others are still
ebruary 10) after passing 180
ters.
other set the filters were sub-
t intervals during five mouths
currents, beginning at the
1 liter in 4 to 7½ hours and in-
to 1 liter in 1½ minutes. These
Fig. 3) consisted of columns c
timeters high, of sand, 30° to
., screened through 30 to 50
per inch.
100°.
tus packed rather tightly.
e filters have stood this ex-
trying test, the infusions remaining intact.

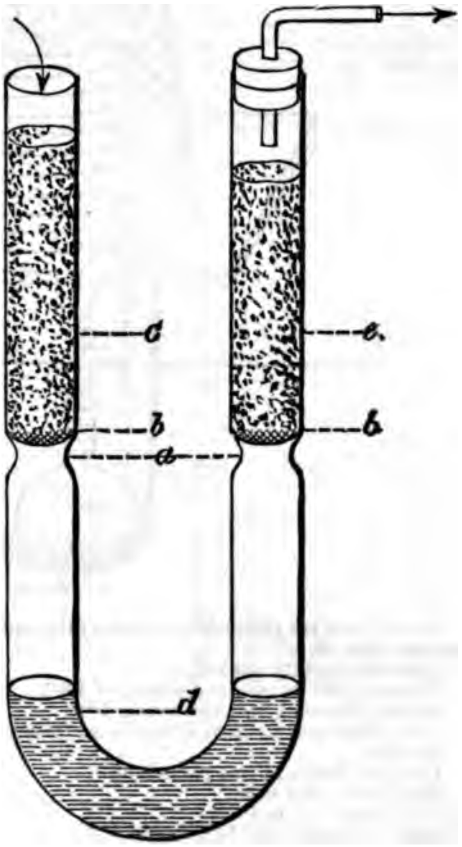

FIG. 2.

experiments go to show that as long as the grains are small all the substances
lter perfectly all organisms from the air passing through them.
**XPERIMENTS IN FILTERING BACTERIA AND THEIR GERMS FROM LIQUIDS.**—
experiments there were tried (see Fig. 1) three sets of filtrations, the liquids
spectively:
sh infusions.
trid infusions.
d water.
first set the filters employed were sand, charcoal, and animal charcoal, the
each being 100°, and asbestus in columns of 15 centimeters. All failed to
t the germs except two filters out of twelve of asbestus and the finest animal
; the remaining asbestus and coarser animal charcoal 15°, and vegetable
in all grades failing equally with the sand.
ar filters were used in the second set (filtration of putrid infusions), except
charcoal filters nothing finer was used than vegetable 25° to 50° and animal

In this set only tightly packed asbestus stood the test; in all the others the infusion passed through turbid.

But it will be noticed that in the previous set the finest animal charcoal filtered perfectly an infusion that became putrid during the process.

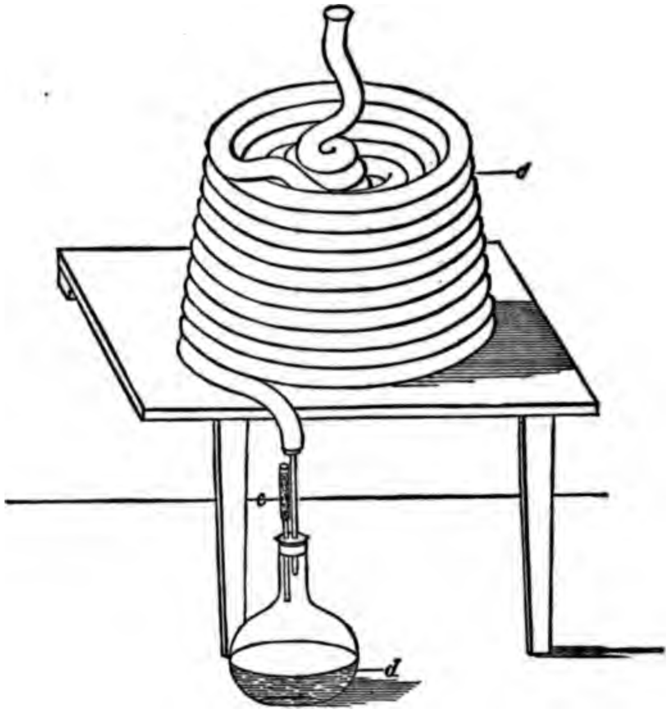

FIG. 4.

In the third set (filtration of water) the substances tested were columns 15 centimeters high of:

Asbestus, tightly packed.
Charcoal, 25° to 50°, and others of 100°.
Animal charcoal, 15°, and others 100°.
Loess from near Council Bluffs, Iowa (taken 40 feet below the surface).
Kaolin.
One part kaolin, three parts sand.
One kaolin, one sand.
Coal ashes, 10° to 100°.
Sand 25° to 30°, 30° to 50°, and 100°.

The experiments were conducted so that only a drop or two of water should reach the infusion at first; more water being passed after intervals of several days, where the infusion remained uninfected.

Of these the tightly packed asbestus stood repeated filtrations during 10 days, after which the infusion putrefied.

Of the finest animal charcoal filters one out of four filtered out the germs.

The other three stood repeated filterings during 17 to 20 days, after which the infusion became infected.

The coal ashes were subjected to repeated filtrations during 10 to 19 days, after which the infusions putrefied.

The infusions under the loess filters broke down after from 6 to 8 days.

Those under the kaolin and the mixtures of kaolin and sand all broke down after from 1 to 8 days (although only a few drops had passed in each case), excepting one out of six of pure kaolin, which kept for 19 days, and one out of six of kaolin and sand, in equal parts, which kept 20 days. In all others, the first drop that passed through infected the infusion. And it is probable that in the repeated filtrations, except in the one case of the finest animal charcoal, there was either a differential filtration, or that only so few germs succeeded in passing that a much longer time than usual was required for the infusion to assume the opalescence that betrays infection.

We now made a bold jump from columns of 15 centimeters to columns of 22 and 100 feet.

Of these we have thus far tried only sand of mixed grain 18° to 100°.

To obtain sterilized columns of such a length the sand was intensely heated and poured into lead pipe *c* (Fig. 4), which was then coiled. It was then placed in a furnace and heated to between 250° and 300° C., and then the lower end attached to the flask containing the infusion *d*, and ventilated through a tube protected by sterilized asbestus, *e*.

The whole was then allowed to rest several weeks to be sure that the infusion had been properly sterilized. The pipe was then very slowly filled with tap-water. *The first water that passed through each of the 22 and 100 foot columns carried infection with it.*

Although our experiments have thus far been more of a tentative character, and preliminary to quantitative work, they permit us to draw a few sharply-defined conclusions:

I. All the substances operated on are excellent filters in eliminating germs from *infected air* passed through them, except when they are of a coarse grain 10° to 20°, when the interstitial cavities become probably much less labyrinthine. And all these filters withstood the test of currents having many thousand times the maximum velocity attained in the soil.

II. All natural substances tried thus far, except the finest animal charcoal, and perhaps tightly-packed asbestus, failed to eliminate wholly the germs from liquids.

In the only natural soils tried, the sand, loess, and kaolin, we find in the sand an absolute absence of filtering power as regards germs in water, which would probably be as evident in columns of 10,000 feet as of 100 feet. In the loess, and in the much more compact kaoline on the other hand, there is evidence of a greater filtering power. In these cases it is not unlikely that we shall find that somewhat longer columns will eliminate the germs from the first water passing through; and that with them the filtering capacity is merely a question of the relation of length of column to amount of water.

At this point in our work, it seems as though the filtering capacity were wholly dependent on the size and intricacy of the interstitial cavities; and that in dry-air filters there is a critical limiting point beyond which there is no filtering.

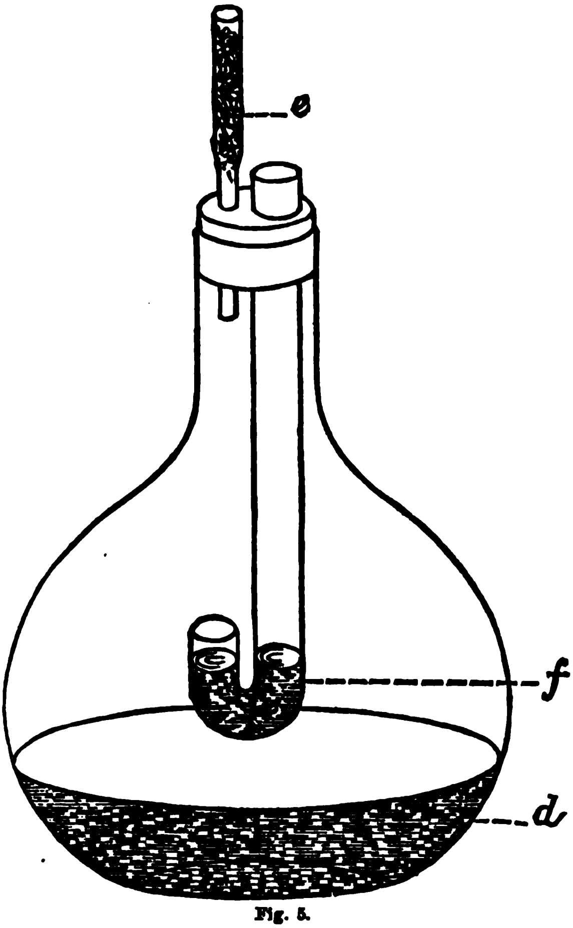

Fig. 5.

And the same remarks seem to be true in different degrees with regard to the filtration of liquids. Here far greater fineness and compactness of grain and intricacy of passage are needed than are requisite for air filtration. While sand of 20° is an excellent air filter, sand of 100° in long columns is worthless for water, and the critical limiting point below which soils begin to exercise any filtering action probably verges on the size of grain in an impalpable powder.

*From these results it appears very clearly that sand interposes absolutely no barrier between wells and the bacterial infection from cess-pools, cemeteries, &c., lying, even at great distances, in the lower wet stratum of sand. And it appears probable that a* DRY GRAVEL *or possibly a* DRY VERY COARSE SAND *interposes no barrier to the free entrance into houses built upon them of these organisms which swarm in the ground-air around leaching cess-pools, leaky drains, &c., or in the filthy made-ground of cities.*

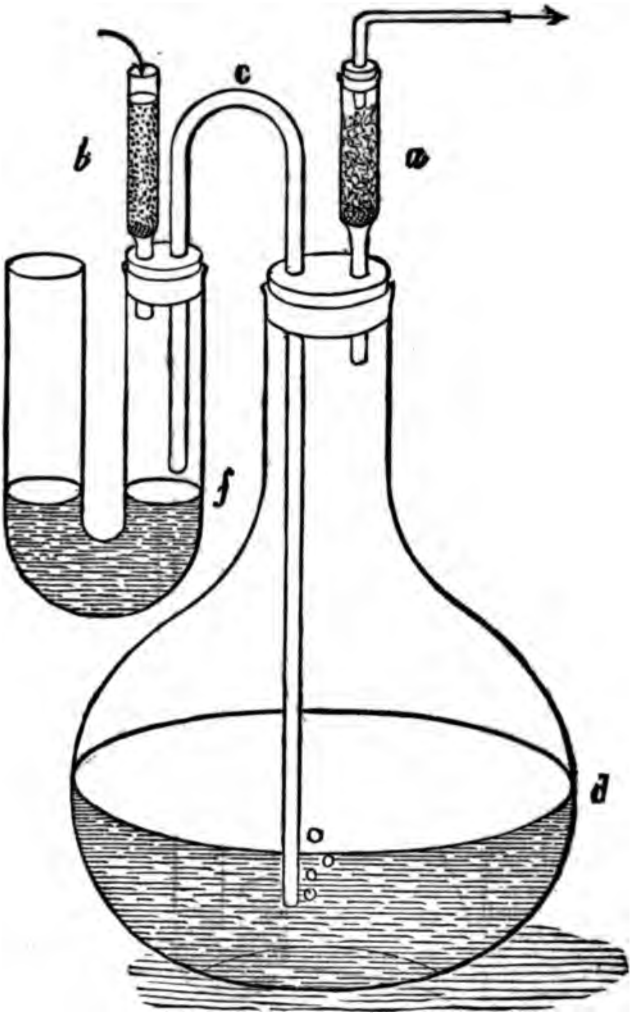

FIG. 6.

And from the results obtained from the two series of experiments, viz, in filtering air and in filtering water, we can now draw one very important practical conclusion which cannot be too strongly emphasized: *That a house may be built on a thoroughly dry body of sand or gravel, and its cellar may be far above the level of the ground-water at all times, and it may yet be in danger of having the air of its rooms contaminated by the germs from leaching cesspools and vaults; for, if the drift of the leaching be toward the cellar, very wet seasons may extend the polluted moisture to the cellar walls, whence, after evaporation, the germs will pass into the atmospheric circulation of the house.*

We are, however, only at the beginning of the subject. Our next studies will be in part the determination of influence of size of grains and character of interstitial passage; the influence upon the germs of length of time occupied in transit; of temperature and pressure, and of presence or absence of nourishment in the liquid. And all of our experiments will be extended to the different soils and to some porous rocks. We are also about to determine the presence or absence of germs at various depths in different soils.

The important question now in controversy regarding the ability of germs of bacteria or other particulate matter to disentangle themselves from a liquid and become suspended in the atmosphere, has an important bearing upon the relation between ground-water and ground-air.

For this reason we have carried on several series of experiments in this connection.

Referring to a full description of the methods and apparatus for details, I will give here only a general outline, with the results.

I. In the first series (see Fig. 5) water, sewage, and putrefied substances (*f*) were suspended in flasks over a sterilized beef infusion (*d*) in a room where the temperature ranged between 20° and 35° C. At the end of 80 days the infusions were intact.

After the furnace fire was started in the autumn, the heat from the register which was below the flasks seems to have caused the transmission of the infection from the water and putrid infusions to the infusion in three out of five flasks, while the remaining two are still intact after five and six months, respectively, although repeatedly exposed to temperatures of 37° to nearly 42° C.

II. In another series (see Fig. 6) of three flasks, during more than a month, air filtered through asbestus (*b*) was aspirated from immediately above the surface of the infected fluid (*f*) and made to pass through the infusion (*d*) at the rate of 3½ liters per day. In all three flasks, after nearly six months, the infusion is still intact.

III. A third series was instituted to determine the possibility, suggested by Colonel Waring, of germs becoming liberated from the liquid by the bursting of bubbles of gas or common air.

For this purpose air was drawn by extremely gentle aspiration (Fig. 7) through the sewage (*f*), the bubbles breaking in the atmosphere above, whence the air was aspirated so as to pass through the infusion (*d*).

Although the formation of the bubbles was gentler than in much natural fermentation (only two-third liters in some cases per day being aspirated), the infusion in all three flasks became infected within a few days.

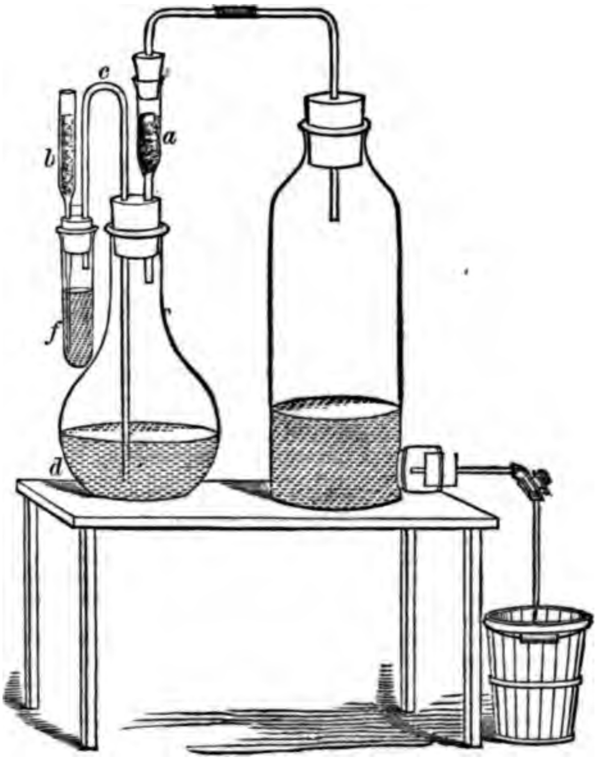

FIG. 7.

These results are positive as far as they go, and show that particulate matter, however minute, cannot pass from the surface of a quiet liquid into the atmosphere under the conditions surrounding our experiments, whereas, on the other hand, the bursting of even the gentlest bubbles can effect such a transfer. They are not, however, sufficiently positive with regard to higher temperatures; needing to be repeated in breeding boxes at regulated temperatures.

Experiments are also needed as to the effects of growths of mold on the surface in forming a transitional condition from which a transfer might be effected; also as to the influence of the evaporation to dryness of infected moisture raised by capillary attraction.

We are indebted to Dr. Sternberg, U. S. A., and to Dr. W. S. Bigelow, for important aid in microscopic examination.

### DETAILS OF THE WORK, WITH TABLES.

In studying the deportment of soils and of artificial filters, with reference to the transmissions of germinal forms of matter, two general series of experiments suggest themselves:

1. *On their action as filters for air or gases generally.*
2. *On their action as filters for water and other liquids.*

### FIRST SERIES OF EXPERIMENTS—AIR-FILTRATIONS.

We have in this series two problems to solve:

1. *Whether the filters employed will protect the infusions when the vessels containing them simply stand exposed to the air*, when the air-currents consequently are very feeble, being induced by slight fluctuations of temperature, pressure, &c., of the atmosphere.

As the filtering capacities of the materials employed are affected both by the length and the porousness of the filtering column, the experiments should be tried with filters of varying thickness, and of different degrees of compactness, in the case of fibrous filters as asbestus, or of different degrees of fineness, in granular filters as charcoal, sand, &c.

2. *Whether the filters will protect the infusions when air is forced through them.*

Here we have to determine how great a volume of air can be conducted through filters of a certain length and of varying degrees of compactness or of fineness in a slow and uniform stream, and again how rapidly a given volume of air can be filtered.

Furthermore, as the experiments have a practical bearing, they should be tried under all the natural conditions of the soils as regards moisture, *i. e.*, with dry, partially saturated, and completely saturated filters.

The results of the experiments, so far as we are prepared to communicate them, are given in the tables below, which contain the full data. Table I contains the tests of the first problem with dry filters; Table II, with wet filters; while Table III and IV give respectively the results of slow and rapid filtrations. Accompanying these tables are graphical representations of the lengths of time during which the different infusions have remained fresh. The figures on the horizontal lines represent days (in Table II, first series, weeks), the vertical lines the number of days and parts of days, therefore, that the infusions remained intact. The times given are the periods between the preparation of the experiments and the first appearance of decomposition to the naked eye. Where this could only be told within certain limits dotted lines in continuation of the vertical lines represent the extreme limits. The lines running above the scale and terminating in arrow-points denote infusions which are still clear.

With the dry filters we have experimented, as will be seen, with asbestus, sands, and charcoals (both vegetable and animal) of various degrees of fineness, mixtures of sand with clay in different proportions, pure clay, coal-ashes, and one natural soil, a loess from the vicinity of Council Bluffs, taken some forty feet below the surface. As wet filters asbestus, sand, charcoals, and loess have been tried. For slow quantitative filterations dry asbestus, sands, charcoals, and for rapid filtrations dry asbestus and sands have been tested.

For asbestus filters the so-called *carded asbestus*,* which can now be obtained commercially, was employed. For sand filters the very pure sand from the Berkshire sand-works has up to the present time been used. This is a very pure, crushed quartz. For animal charcoal filters both bone-black and very fine charcoal from blood, &c., were used. The sands and charcoals employed were carefully sifted through sieves containing ten to one hundred meshes to the inch. The fineness of the sands is indicated in degrees. Thus a sand marked in the tables 25–30°, for instance, is one which will pass entirely through a sieve containing 25 meshes to the inch, and be retained completely by a sieve of 30 meshes to the inch; sand marked 100° contains sand of every degree of fineness, above one-hundredth of an inch up to the finest powder.

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* The use of asbestus in this form for the purpose of preserving infusions in bulk for subsequent experiments cannot be too highly recommended, as the carded asbestus is as convenient and serviceable a filter as cotton, and can be at once sterilized by direct ignition in the open flame of the burner. It has been our practice to prepare the infusions for experiments in quantity, to store them in large flasks, the necks of which were then loosely stoppered with a wad of asbestus. Although some of these flasks have been repeatedly opened, while others have remained undisturbed for weeks, we have never had in either case an infusion decompose. It is simply necessary after using a portion of an infusion for experiments to reboil the remainder and reinsert the freshly-ignited plug of asbestus.

*Table I, first series—Dry filters.*

For these experiments, tubes (Fig 1), with a contraction in the middle, and flasks, with the necks contracted at the base, for the purpose of supporting the filters, were employed. In three of the first experiments with sand filters the necks of the tubes employed were plugged with a little asbestus, the sand being filled in on to these, but as it seemed possible that these simple plugs might themselves act as filters, in all subsequent experiments disks of fine copper gauze (ordinarily of 80 meshes to the inch), of a diameter somewhat greater than that of the tubes, &c., were fitted carefully into the necks. Whenever very fine filters, as the sands and charcoals of 100°, coal-ashes and loess were used, a thin layer of the same materials in a coarser form, or of coarse sand, was interposed between the gauze and the filter, in order to prevent the latter, so far as possible, from sifting through into the infusions.

In preparing the experiments great care must be exercised in order to insure a thorough sterilization of the tubes, filters, and infusions, and we consequently describe below our method of experimenting in detail. That the method can be relied upon is, we think, clearly shown in the results of the experiments. Out of nearly two hundred tubes and flasks prepared with filters there are only seven cases in which the infusions were undoubtedly not sterilized. Of these, two are milk samples and three are hay infusions, the two, as is well known, most difficult substances to sterilize. Besides these there is one beef and one fish infusion. Of the fifty-seven tubes, &c., for the water filtrations of the second series of experiments, all were completely sterilized.

The tubes, after being thoroughly cleansed, were filled with the infusions about half way up to their necks; the copper disks were fitted in, and the tubes then heated in a paraffin bath for from one-half to three-quarters of an hour, at as high a temperature as possible. In some cases the tubes and flasks were heated very strongly before being filled. This, though not essential, is, perhaps, in all cases, an advisable precaution. The temperature of the paraffin bath was usually about 110°. The bath consisted of a copper cylinder some twenty inches in length, and in this the tubes, strung on wires, were suspended, immersed in the paraffin to within an inch of their tops. In this way they were uniformly heated throughout their entire lengths. On the removal of a tube from the bath the portion above its neck was immediately very strongly heated over the direct flame of the burner, the tube being held in a slanting position, and the hot filters added as quickly as possible. Whenever asbestus was employed as a filter it was added in small portions, each successive portion being first ignited for a few seconds over the burner. The sands, the loess, and the coal-ashes were heated very intensely in closed vessels. The animal and vegetable charcoals were heated in shallow pans for a long time, in an air-bath, at temperatures of 250° to 275°, and, while the tubes were being filled, directly over the naked flame of the burner, at temperatures as near their ignition points as possible.

The flasks were occasionally boiled in paraffin baths, as, for example, in the milk experiments; more frequently, however, directly over the burner. The boiling was in all cases maintained for about an hour, and the filters were then filled in the manner just described.

The infusions were in most cases boiled again after the insertion of the filters into the tubes, &c., as an additional precaution. All the utensils employed in filling the tubes were also strongly heated. By means of these precautions we were assured of the absolute sterility of the filters.

With every set of tubes and flasks a few were put up in the same way, but without the filters, for comparison, and as control-experiments. Some of these were left entirely open; in others the disks of copper gauze were inserted. Besides these a large number of capsules, flasks, &c., containing infusions, were exposed from time to time to see if the air of the laboratory invariably contained germs. Many of the infusions protected by filters were at times exposed in other places, as in the cellar, in a stable, &c.

Of the infusions in the open flasks and capsules, none remained uninfected for more than thirty hours, with the single exception of the one given in the table (No. II), which remained fresh for nearly three days. The conditions were peculiarly favorable for the decomposition of the infusions and the rapid development of bacterial growths, as the climate is an exceedingly damp one and the temperature in the laboratory during the summer months was over 80° Fahr. for the greater part of the time, and often ran above 90° Fahr.

In not a single instance either has a tube left open, or covered simply by a disk of copper gauze, escaped infection from the atmosphere, though the time required for inoculation is in most cases, as would naturally be expected, somewhat longer than that for the more exposed flasks, and especially for the capsules. The tubes containing copper guaze seemed to have remained fresh on the average slightly longer than the entirely open tubes, as will be seen by a study of the tables, the open tubes ranging from one to eleven days (No. 93 eight days and No. 126 eleven days), while those with copper guaze range from nearly one to sixteen days, No. 34 remaining fresh eleven, Nos. 128 and 129 twelve, No. 146 fourteen, and No. 101 sixteen days, respectively.

Nor are the infusions protected by simply drawing out the tubes containing them at any point to long capillary tubes, as experiments 27–29 show. On the other hand, No. 30, in which the capillary tube was bent over so as to open downward, has remained intact.

This fact has been observed before, that infusions will often remain uninfected when there is direct communication with the outer air through a tube opening downward or through a tube bent into a series of U-shaped curves, and it proves simply that the microscopic organisms floating in the air settle upon objects in the same manner as the grosser, visible particles of dust.

Of the beef, fish, hay, cucumber, and beet infusions, protected by sterilized filters of asbestus, coal-ashes, loess, fine animal charcoal, sands, and vegetable charcoals of 25° and upwards, none have as yet decomposed in consequence of infiltration of germs (with the single exception of No. 151, which contained only $1^{mm}$ of sand, 30°–50°,) though many of them have already been kept six or seven months, and the filter columns in some cases are only $2^{mm}$ to $5^{mm}$ in length. Nos. 12 and 13 decomposed within a few days after brief exposures to the air.

Extremely interesting results are furnished by experiments 20, 124, 153, and 154. In these experiments, the results of which are apparently at variance with those of all others of the series, the infusions finally showed the presence of filamentous fungi and subsequently of bacterial growths after remaining intact for long periods of time. These tubes all contained, it will be seen, very short columns of the finest sand, the coarsest grains of which were less than one one-hundredth of an inch in diameter, while the finest formed an almost impalpable powder. These filters barely covered the upturned edges of the gauze bottoms on which they rested, and in spite of every precaution taken to fit the latter very tightly against the sides of the tubes, small portions of the finest sand from the uppermost exposed layers gradually worked their way down behind these edges into the infusions, carrying away with them still finer particles of germinal matter, which had accumulated on the surfaces of the filters and which then infected the infusions. In several cases where this sand or other very fine filters were employed, minute quantities of the filtering material from the lower layers were gradually sifted through the gauze into the infusions, in consequence of the jarring and shaking to which the tubes were subjected during the daily examinations, but in no cases were the latter infected where the gauzes were completely covered by even two or three millimeters only of the filter, where consequently the uppermost exposed layer could not work its way in. A more striking proof that germs from the air accumulate upon the surfaces of the filters and are prevented by the latter from passing down into the infusions could hardly be furnished than by these few apparent failures of fine sand to act as filters. Coarse animal charcoal of 15° did not act as a filter, as is seen in experiments 63 to 68; nor do short columns of sand of 10° to 20° afford a sure protection to the infusions for any great length of time, three of these tubes having already decomposed.

The results of the milk experiments are more difficult to explain satisfactorily. These have all broken down. One of them, No. 110, was evidently not sterilized, as it underwent putrefactive decomposition in about three days, while others, Nos. 103, 105, and 112, which contained asbestus filters of various lengths, showed the first indications of change at the expiration of twenty-one, sixty, and fifty-four days respectively. No. 105 contained bacteria of putrefaction (*B. termo*) and some cells which are again alluded to below. No. 112 was found upon microscopical examination on December 18 to be still swarming with bacteria.* No. 103 was not examined under the microscope, but undoubtedly contained vibrios.

To explain these decompositions we are driven either to the conclusion that asbestus in these cases signally failed to act as a filter, or that, notwithstanding the long intervals of time which elapsed before the decompositions became manifest to the naked eye, the milk was not absolutely sterilized by the long-continued boiling to which it was subjected.

That asbestus, which has acted as a filter in so many cases in layers of only $1^{mm}$ to $3^{mm}$, should not filter the air in these cases where lengths of 5, 6, and $8^{cm}$ were employed, certainly seems highly improbable. On the other hand, it is by no means impossible that the milk, though boiled for a long time—over an hour in every instance—was not completely sterilized, as it is the most difficult of all cultivating liquids to sterilize, even surpassing old hay infusions in this respect, especially when it has stood exposed to the air for a short time. The only features of the case on this supposition which might occasion surprise are the very protracted intervals during which the milk, in Nos. 105 and 112, remained fresh to all appearance and the subsequent rapidity of decomposition. The temperature[*] during the time of these experiments ranged pretty constantly above 25°, and sometimes even ran as high as 35°, and, as we have seen, all the flasks of boiled milk and all infusions which were exposed to the air at these temperatures, as also some which were protected by filters but were not completely sterilized, decomposed rapidly and within a few days.

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* The term bacteria is used throughout in the general sense, to denote all the forms, as micrococci bacteria, vibrios, spirilla, &c., which Naegeli classifies as *Spaltpilze* or *Schizomycetes*.

It is possible that germs whose vitality was not wholly destroyed may have been encased in indurated, coalesced particles of the milk, and thus prevented from speedily developing.

It is likewise possible that germs, though not devitalized, may have been so changed or enfeebled by the long-continued boiling of the milk as to have been rendered incapable of immediate or active development, and that a vigorous capacity for self-multiplication was restored only after a generation or perhaps a series of generations had succeeded them. Whether this was actually the case in the experiments cited could only have been determined by successive microscopic examinations and prolonged culture experiments, which, under the given experimental conditions, could not have been carried on. If such were, however, the actual conditions, the development may have gone on for some time before it became sufficiently marked to be detected, and the dates given in the tables would not then indicate even approximately the times of incipient decomposition. It certainly would not be impossible for this to happen, for the bacterial growths themselves could not be detected, as in the transparent infusions of beef, hay, &c., through a cloudiness of the liquid, the formation of pellicles on its surface or a mere film on the glass at the edges of the infusion, but their presence could only be discovered through the precipitation of casein, in consequence of the lactic acid or butyric acid fermentation, &c., or through the formation of putrefaction products in large amounts.

It must, however, be observed that, after the first indications of souring or of putrefaction, the decompositions proceeded with marked rapidity, especially in No. 112.

Periodical microscopic examinations are evidently necessary in all filter experiments with milk in order to fully control the results, and in future tests we shall consequently so modify the apparatus as to admit of microscopical examinations without at the same time disturbing the filters. The necessity of microscopical examinations becomes more apparent from an examination of the experiments, Nos. 107 to 109 and 113 and 114.

The decompositions which have here taken place are more difficult still to account for. The milk in these flasks appeared to have remained unchanged for several months; small quantities of casein separated out very slowly, in somewhat granular masses, which remained for the greater part suspended. There were no indications of lactic acid fermentation or of putrefactive decomposition, nor could traces of vibrionic growths or of bacteria of decomposition be found under the microscope, with the aid of a Zeiss one-twelfth inch homogeneous oil-immersion objective, in Nos. 107 and 113, which were opened and examined January 22.

These had, however, an acid reaction, a peculiar disagreeable, oily odor and taste, somewhat like that of stale, unsalted butter, and contained some spherical cells closely resembling colostrum-corpuscles, which were stained by anilin-violet. They had evidently undergone some chemical change. Exposed to the air they underwent the usual fermentation, the casein coagulating in thick curds.

Similar results were obtained from the examination of No. 114 in February (Hartnack, nine, water-immersion objective).

Nos. 108 and 109 gave the same oily odor, &c., but have not as yet been examined microscopically. With these we shall try cultivation tests.

These changes must have taken place either without the action of inferior organisms, *i. e.*, through strictly chemical processes, or else through the development of some form or forms of organisms in so inconsiderable a degree as to escape detection.

Besides the experiments just discussed several tests (Nos. 35 to 58) were tried with unsterilized filters of sand, asbestus, and cotton for comparison with these, the object being to learn whether the germs which these bodies undoubtedly contain in consequence of their previous free exposure to the air would readily be detached from them and fall into the infusions in the tubes and flasks. For all germs deposited upon them from the air, after their insertion into the filter-tubes, they would act as filters as well as the sterilized materials, and only those germs adhering to the lower layers as the tubes were filled could become detached and fall into the infusions. A slight modification in the method of experimentation is here obviously necessary; for should the infusion be maintained at the boiling temperature during and subsequent to the addition of the filters, the germs adhering to their lower surfaces might be destroyed by the steam; while, on the other hand, should the infusions be allowed to cool, wholly or in part, previous to the insertion of the filters, there would be no guaranty that germs had not entered from the air.

In the series of flasks (Nos. 35 to 46) the filters were added directly the infusions ceased to boil after the removal of the flame. The series of tubes (Nos. 47 to 58) were partially cooled directly beneath the flame of a burner, so that the air on entering first passed through this, and was in consequence freed from organisms. The filters were then quickly added, the burner being raised sufficiently to admit of their insertion.

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[*] Tyndall gives about 27° to 32° as favorable temperatures for the development of these lower organisms; Naegeli a temperature of 7°, others 38° to 39° as the most favorable for rapid development.

The results would seem to indicate that the temperature of the flasks was sufficient in most cases to destroy the vitality of the germs on the lower surfaces of the filters, as only three of the twelve infusions have as yet decomposed, while in the tubes only five out of the twelve have escaped infection. It is, however, possible that living germs have not as yet been detached from the filters in these cases. The dates of decomposition afford sufficient proof of the initial sterility of the infusions and the inoculation from the filters in the infected tubes, &c. Should the still undecomposed infusions of this series remain fresh for a long time, we shall try the effect of slight currents of air upon them. The results with these unsterilized filters show the necessity of careful sterilization of all filters.

### *Table II, first series—Wet filters.*

The tubes and flasks were filled precisely as were those of Table I, and while the filters were still quite hot, distilled water, the sterility of which had been insured by protracted boiling, was added until the filters were completely saturated, the water being thrown upon them in a fine stream from a wash-bottle while still violently boiling. The filters in the tubes were kept saturated with water for a long time, a few drops of unsterilized water being subsequently added from time to time to supply the loss by evaporation. They were then allowed to partially dry, and have since been kept moist. Those in the flasks were allowed to gradually dry through evaporation.

While asbestus, coarse and fine sands, fine vegetable charcoal, and loess have, in the great majority of cases, protected the infusions, coarse animal charcoal of 15° (Nos. 11 and 12) failed, as it did in the dry state, to filter out the germs of the air.

Of the remaining seven cases of decomposition, two (Nos. 20 and 23) resulted from incomplete sterilization, one (No. 3) was undoubtedly, and two others (Nos. 1 and 4) were probably caused by subsequent infiltration of unsterilized water, too large a quantity having been incautiously added. This may possibly have been the case likewise with experiment No. 25, though no water was seen to have percolated the filter subsequent to the preparation of the experiment.

It was a matter of some difficulty to keep the filters thoroughly wet and at the same time to prevent the water from running through into the infusions; and it will be observed that the decompositions resulting from infiltration of water were all with filters of sand, a material which signally fails, as is shown in experiments of the second series, to free liquids from their germs.

In No. 22 the decomposition is undoubtedly due to the final entrance of germs through the dry filter, as the infusion remained clear for 164 days, when a filamentous fungus appeared, which rapidly developed. In this experiment an ordinary, wide-necked flask was *very loosely* filled with asbestus to a height of about 2$^{cm}$. After saturation with sterilized water the asbestus was allowed gradually to dry. This is, up to the present time, the only instance of infiltration through a short column of asbestus, as No. 151 of Table I is through sand.

## FIRST SERIES OF EXPERIMENTS.

### AIR-FILTRATIONS.

TABLE I.—*Dry filters.*

| No. | Infusion. | Dimensions of tubes, &c., employed. | Filters. | | Date of experiment. | Subsequent treatment. | No. | Date of decomposition. | Time in— | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Kind. | Length in centimeters. | | | | | Days. | Hours. |
| 1 | Beef ........ | Tubes, 46 by $2^{\mathrm{cm}}$, inner diameter. (See figure 1.) | **Asbestus (loosely packed)** | 14 | June 9 | No. 1, air sucked out several times June 21. | 1 | ........ | ........ | ........ |
| | | | | 7 | | | 2 | ........ | ........ | ........ |
| | | | **Asbestus (tightly packed)** | 7 | | | 3 | ........ | ........ | ........ |
| 4 | | | **Sand, 25° to 30°** ........ | 15 | June 10 | Air sucked out of Nos. 4 and 5 several times June 21. | 4 | ........ | ........ | ........ |
| 5 | | | **Sand, 100°** ........ | 14 | | | 5 | ........ | ........ | ........ |
| 6 | | | | 8 | | | 6 | ........ | ........ | ........ |
| 7 | | | *Open, for comparison* ........ | ........ | June 9 | ........ | 7 | June 11 | **Less than 2 days.** | |
| 8 | | | | | | | 8 | | | |
| 9 | | | | | | | 9 | | | |
| 10 | Beef ........ | Flask, $750^{\mathrm{cm}^3}$ ........ | **Asbestus** ........ | 8 | June 10 | ........ | 10 | ........ | ........ | ........ |
| 11 | Beef ........ | Flask, $750^{\mathrm{cm}^3}$ ........ | *Open* ........ | ........ | June 10 | ........ | 11 | June 12 | **Within 3 days.** | |
| 12*a* | Beef ........ | Tubes, 46 by $2^{\mathrm{cm}}$ ........ | **Sand, 25° to 30°** ........ | 15 | June 9 | No. 12, opened and exposed for 20 minutes June 17 and for 9 hours June 23. | 12*a* | June 25 | **About 2 days, 12 hours.** | |
| 13*a* | | | | 5 | June 9 | No. 13, opened and exposed for 3½ hours June 21, and 24 hours June 25. | 13*a* | June 26 | **Less than 5 days from 1st exposure, within 1 from 2d.** | |
| 14 | | | | 8 | June 9 | No. 14, subsequently employed as a water-filter (see Table III, 2d Ser., Water-filtrations). | 14 | See Table III. | ........ | ........ |
| 15 | Beef ........ | Tubes, 23 by $1^{\mathrm{cm}}$ ........ | **Asbestus plugs in the necks.** | 1 | June 19 | ........ | 15 | ........ | ........ | ........ |
| 16 | | | | | | | 16 | ........ | ........ | ........ |
| 17 | Beef ........ | Tubes, 23 by $1^{\mathrm{cm}}$ ........ | **Sand, 25° to 40°** ........ | 1 | June 19 | ........ | 17 | ........ | ........ | ........ |
| 18 | | | | 0.8 | | | 18 | ........ | ........ | ........ |
| 19 | Beef ........ | Tubes, 23 by $1^{\mathrm{cm}}$ ........ | **Sand, 100°** ........ | 1.5 | June 19 | ........ | 19 | ........ | ........ | ........ |
| 20*b* | | | | *b* | | | 20*b* | July 25 | 36*b* | ........ |

## FIRST SERIES OF EXPERIMENTS—Continued.

### AIR-FILTRATIONS—Continued.

### TABLE I.—*Dry filters*—Continued.

| No. | Infusion. | Dimensions of tubes, &c., employed. | Filters. |  | Date of experiment. | Subsequent treatment. | No. | Date of decomposition. | Time in— |  |
|---|---|---|---|---|---|---|---|---|---|---|
|  |  |  | Kind. | Length in centimeters. |  |  |  |  | Days. | Hours. |
| 21 | Beef | Test-tubes with rubber stoppers, containing tubes 5mm in diameter, plugged with asbestus. | **Asbestus** | 1 | June 19 | ........ | 21 | ........ | ........ | ........ |
| 22 |  |  |  |  |  |  | 22 | ........ | ........ | ........ |
| 23 | Beef | Tubes, 46 by 2cm | *Open* | ........ | June 23 | ........ | 23 | June 24 | **About 1 day, 12 hours.** |  |
| 24 |  |  |  |  |  |  | 24 | June 24 |  |  |
| 25 | Beef | Tube, 23 by 1cm |  |  |  |  | 25 | June 30 | 7 | ........ |
| 26c |  | Test-tube containing pieces of copper gauze. |  |  |  |  | 26c | June 24 | 1 | ........ |
| 27 | Beef | No. 27, test-tube drawn out at the middle to a capillary tube 8cm in length.<br>Nos. 28 and 29, test-tubes drawn out at the end to long capillary tubes.<br>No. 30, test-tube drawn out to a capillary tube and bent over. | *Open* | ........ | June 28 | ........ | 27 | July 2 | 4 | ........ |
| 28 |  |  |  |  |  |  | 28 | July 12 | 14 | ........ |
| 20 |  |  |  |  |  |  | 29 | July 2 | 4 | ........ |
| 30 |  |  |  |  |  |  | 30 | ........ | ........ | ........ |
| 31 | Beef | Tubes, 23 by 1cm | *Open* | ........ | July 13 | ........ | 31 | July 15 | **Less than 2 days.** |  |
| 32 |  |  | *Copper gauze in the necks* | ........ | July 13 | ........ | 32 | July 19 | 6 | ........ |
| 33 |  |  |  |  |  |  | 33 | July 19 | 6 | ........ |
| 34 |  |  |  |  |  |  | 34 | July 24 | 11 | ........ |
| 35 |  |  | **Asbestus, not ignited** | 4 | July 27 | ........ | 35 | ........ | ........ | ........ |
| 36 |  |  |  |  |  |  | 36 | ........ | ........ | ........ |
| 37 |  |  |  |  |  |  | 37 | ........ | ........ | ........ |
| 38 |  |  | **Sand, 30° to 50°, unignited.** |  |  |  | 38 | ........ | ........ | ........ |
| 39 |  |  |  |  |  |  | 39 | ........ | ........ | ........ |
| 40 |  |  | **Sand, 25° to 30°, unignited.** |  |  |  | 40 | ........ | ........ | ........ |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 41 | Beef (See note *d.*) | Flasks, of $250^{cc}$ | *Absorbent cotton, unsterilized. | 4 | Aug. 2 | ...... | 41 | ...... | ...... | ...... |
| 42 | | | | | | | 42 | ...... | ...... | ...... |
| 43 | | | | | | | 43 | ...... | ...... | ...... |
| 44 | | | †Non-absorbent cotton, unsterilized. | | | | 44 | Sept. 7 | 36 | ...... |
| 45 | | | | | | | 45 | Sept. 21 | 50 | ...... |
| 46 | | | | | | | 46 | Sept. 9 | 38 | ...... |
| 47 | Beef (See note *d.*) | Tubes, 23 by $1^{cm}$ | Unignited asbestus | 1 | July 27 | ...... | 47 | ...... | ...... | ...... |
| 48 | | | | | | | 48 | ...... | ...... | ...... |
| 49 | | | | | | | 49 | Aug. 1 | 35 | ...... |
| 50 | | | | | | | 50 | Nov. 12 | 108 | ...... |
| 51 | | | Sand, 30° to 50°, unignited. | 1 to 2 | | | 51 | Aug. 10 | 44 | ...... |
| 52 | | | | | | | 52 | July 30 | 33 | ...... |
| 53 | | | | | | | 53 | Aug. 2 | 36 | ...... |
| 54 | | | | | | | 54 | Nov. 18 | 114 | ...... |
| 55 | | | Absorbent cotton, unsterilized. | 1 | | | 55 | Between Sept. 25 and Oct. 13.‡ | 60 to 78 | ...... |
| 56 | | | | | | | 56 | ...... | ...... | ...... |
| 57 | | | | | | | 57 | ...... | ...... | ...... |
| 58 | | | | | | | 58 | ...... | ...... | ...... |
| 59 | Beef | Tubes, 23 by $1^{cm}$ | Charcoal 25° to 30° | 1.5 | Aug. 8 | ...... | 59 | ...... | ...... | ...... |
| 60 | | | | | | | 60 | ...... | ...... | ...... |
| 61 | | | Charcoal, 100° | | | | 61 | ...... | ...... | ...... |
| 62 | | | | | | | 62 | ...... | ...... | ...... |
| 63 | Beef | Tubes, 23 by $1^{cm}$ | Animal charcoal, 15° | 1 to 2 | Aug. 28 | ...... | 63 | Sept. 7 | 10 | ...... |
| 64 | | | | | | | 64 | Sept. 18 | 21 | ...... |
| 65 | | | | | | | 65 | Sept. 7 | 10 | ...... |
| 66 | | | | | | | 66 | Oct. 13 | Unknown, between 28 and 46 days. | |
| 67 | | | | | | | 67 | Sept. 10 | 13 | ...... |
| 68 | | | | | | | 68 | Sept. 7 | 10 | ...... |
| 69 | Beef | Tubes, 23 by $1^{cm}$ | Animal charcoal, 100° | 0.7 | Oct. 19 | ...... | 69 | ...... | ...... | ...... |
| 70 | | | | 0.7 | | | 70 | ...... | ...... | ...... |
| 71 | | | | 0.2 | | | 71 | ...... | ...... | ...... |
| 72 | | | | 0.3 | | | 72 | ...... | ...... | ...... |
| 73 | | | | 0.1 | | | 73 | ...... | ...... | ...... |
| 74 | | | | 0.4 | | | 74 | ...... | ...... | ...... |
| 75 | Beef | Tubes, 23 by $1^{cm}$ | *Open* | ...... | ...... | ...... | 75 | Oct. 24 | 5 | ...... |
| 76 | | | | | | | 76 | | | |

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* Surgeon's cotton. † Cotton seed for steamboat mattresses, &c. ‡ The tubes were not examined from the 26th of September to the 12th of October, inclusive.

## FIRST SERIES OF EXPERIMENTS—Continued.

### AIR-FILTRATIONS—Continued.

### TABLE I.—*Dry filters*—Continued.

| No. | Infusion. | Dimensions of tubes, &c., employed. | Filters. | | Date of experiment. | Subsequent treatment. | No. | Date of decomposition. | Time in— | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Kind. | Length in centimeters. | | | | | Days. | Hours. |
| 21<br>22 | Beef ........ | Test-tubes with rubber stoppers, containing tubes $5^{mm}$ in diameter, plugged with asbestus. | **Asbestus** ........ | 1 | June 19 | ........ | 21<br>22 | ........<br>........ | ........<br>........ | ........<br>........ |
| 23<br>24 | Beef ........ | Tubes, 46 by $2^{cm}$ ........ | *Open* ........ | ........ | June 23 | ........ | 23<br>24 | June 24<br>June 24 | **About 1 day, 12 hours.** | |
| 25<br>26c | Beef ........ | Tube, 23 by $1^{cm}$ ........<br>Test-tube containing pieces of copper gauze. | | | | | 25<br>26c | June 30<br>June 24 | 7<br>1 | ........<br>........ |
| 27<br>28<br>29<br>30 | Beef ........ | No. 27, test-tube drawn out at the middle to a capillary tube $8^{cm}$ in length.<br>Nos. 28 and 29, test-tubes drawn out at the end to long capillary tubes.<br>No. 30, test-tube drawn out to a capillary tube and bent over. | *Open* ........ | ........ | June 28 | ........ | 27<br>28<br>29<br>30 | July 2<br>July 12<br>July 2<br>........ | 4<br>14<br>4<br>........ | ........<br>........<br>........<br>........ |
| 31<br>32<br>33<br>34 | Beef ........ | Tubes, 23 by $1^{cm}$ ........ | *Open* ........<br>*Copper gauze in the necks* | ........<br>........ | July 13<br>July 13 | ........<br>........ | 31<br>32<br>33<br>34 | July 15<br>July 19<br>July 19<br>July 24 | **Less than 2 days.**<br>6<br>6<br>11 | <br>........<br>........<br>........ |
| 35<br>36<br>37 | | | **Asbestus, not ignited** .... | 4 | July 27 | ........ | 35<br>36<br>37 | ........<br>........<br>........ | ........<br>........<br>........ | ........<br>........<br>........ |
| 38<br>39<br>40 | | | **Sand, 30° to 50°** } **unignited.**<br>**Sand, 25° to 30°** } | | | | 38<br>39<br>40 | ........<br>........<br>........ | ........<br>........<br>........ | ........<br>........<br>........ |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 41 | Beef (See note d.) | Flasks, of $250^{cc}$ | * Absorbent cotton, unsterilized. | 4 | Aug. 2 | .......... | 41 | .......... | .......... | .......... |
| 42 | | | | | | | 42 | .......... | .......... | .......... |
| 43 | | | | | | | 43 | .......... | .......... | .......... |
| 44 | | | † Non-absorbent cotton, unsterilized. | | | | 44 | Sept. 7 | 36 | .......... |
| 45 | | | | | | | 45 | Sept. 21 | 50 | .......... |
| 46 | | | | | | | 46 | Sept. 9 | 38 | .......... |
| 47 | Beef (See note d.) | Tubes, 28 by $1^{cm}$ | Unignited asbestus | 1 | July 27 | .......... | 47 | .......... | .......... | .......... |
| 48 | | | | | | | 48 | .......... | .......... | .......... |
| 49 | | | | | | | 49 | Aug. 1 | 35 | .......... |
| 50 | | | | | | | 50 | Nov. 12 | 108 | .......... |
| 51 | | | Sand, 30° to 50°, unignited. | 1 to 2 | | | 51 | Aug. 10 | 44 | .......... |
| 52 | | | | | | | 52 | July 30 | 33 | .......... |
| 53 | | | | | | | 53 | Aug. 2 | 36 | .......... |
| 54 | | | | | | | 54 | Nov. 18 | 114 | .......... |
| 55 | | | Absorbent cotton, unsterilized. | 1 | | | 55 | Between Sept. 25 and Oct. 13.‡ | 60 to 78 | .......... |
| 56 | | | | | | | 56 | .......... | .......... | .......... |
| 57 | | | | | | | 57 | .......... | .......... | .......... |
| 58 | | | | | | | 58 | .......... | .......... | .......... |
| 59 | Beef | Tubes, 28 by $1^{cm}$ | Charcoal 25° to 30° | 1.5 | Aug. 8 | .......... | 59 | .......... | .......... | .......... |
| 60 | | | | | | | 60 | .......... | .......... | .......... |
| 61 | | | Charcoal, 100° | | | | 61 | .......... | .......... | .......... |
| 62 | | | | | | | 62 | .......... | .......... | .......... |
| 63 | Beef | Tubes, 28 by $1^{cm}$ | Animal charcoal, 15° | 1 to 2 | Aug. 28 | .......... | 63 | Sept. 7 | 10 | .......... |
| 64 | | | | | | | 64 | Sept. 18 | 21 | .......... |
| 65 | | | | | | | 65 | Sept. 7 | 10 | .......... |
| 66 | | | | | | | 66 | Oct. 13 | Unknown, between 28 and 46 days. | |
| 67 | | | | | | | 67 | Sept. 10 | 13 | .......... |
| 68 | | | | | | | 68 | Sept. 7 | 10 | .......... |
| 69 | Beef | Tubes, 28 by $1^{cm}$ | Animal charcoal, 100° | 0.7 | Oct. 19 | .......... | 69 | .......... | .......... | .......... |
| 70 | | | | 0.7 | | | 70 | .......... | .......... | .......... |
| 71 | | | | 0.2 | | | 71 | .......... | .......... | .......... |
| 72 | | | | 0.6 | | | 72 | .......... | .......... | .......... |
| 73 | | | | 0.1 | | | 73 | .......... | .......... | .......... |
| 74 | | | | 0.4 | | | 74 | .......... | .......... | .......... |
| 75 | Beef | Tubes, 28 by $1^{cm}$ | *Open* | .......... | .......... | .......... | 75 | Oct. 24 | 5 | .......... |
| 76 | | | | | | | 76 | | | |

* Surgeon's cotton. † Cotton seed for steamboat mattresses, &c. ‡ The tubes were not examined from the 26th of September to the 12th of October, inclusive.

## FIRST SERIES OF EXPERIMENTS—Continued.

### AIR-FILTRATIONS—Continued.

### TABLE I.—*Dry Filters*—Continued.

| No. | Infusion. | Dimensions of tubes, &c., employed. | Filters. | | Date of experiment. | Subsequent treatment. | No. | Date of decomposition. | Time in— | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Kind. | Length in centimeters. | | | | | Days. | Hours. |
| 77 | Beef .......... | Tubes, 23 by $1^{cm}$ .......... | **Coal-ashes, 10° to 100°** . | 0.8 | Nov. 3 | .......................... | 77 | .......... | .......... | .......... |
| 78 | | | | 2 | | | 78 | .......... | .......... | .......... |
| 79 | | | | 1 | | | 79 | .......... | .......... | .......... |
| 80 | | | | 1 | | | 80 | .......... | .......... | .......... |
| 81 | | | | 1.2 | | | 81 | .......... | .......... | .......... |
| 82 | | | | 0.7 | | | 82 | .......... | .......... | .......... |
| 83 | | | *Open* .................... | .......... | | | 83 | Nov. 5 | 2 | .......... |
| 84 | Beef .......... | Tubes, 23 by $1^{cm}$ .......... | **Sand 10° to 20°** .......... | 3 | Nov. 4 | .......................... | 84 | Dec. 7 | 33 | .......... |
| 85 | | | | | | | 85 | Dec. 22 | 48 | .......... |
| 86 | | | | | | | 86 | .......... | .......... | .......... |
| 87 | | | | 6 | | | 87 | Jan. 5 | 62 | .......... |
| 88 | | | | | | | 88 | .......... | .......... | .......... |
| 89 | | | | | | | 89 | .......... | .......... | .......... |
| 90 | | | | 9 | | | 90 | .......... | .......... | .......... |
| 91 | | | | | | | 91 | .......... | .......... | .......... |
| 92 | | | | | | | 92 | .......... | .......... | .......... |
| 93 | Beef .......... | .......................... | *Open*.................... | .......... | Nov. 4 | .......................... | 93 | Nov. 12 | 8 | .......... |
| 94 | | | | | | | 94 | Nov. 10 | 6 | .......... |
| 95 | Beef .......... | Tubes, 23 by $1^{cm}$ .......... | **Loess** .................... | 1 | Nov. 4 | .......................... | 95 | Tube broken Nov. 5 | .......... | .......... |
| 96 | | | | 1 | | | 96 | .......... | .......... | .......... |
| 97 | | | | 1.3 | | | 97 | .......... | .......... | .......... |
| 98 | | | | 1.5 | | | 98 | .......... | .......... | .......... |
| 99 | | | | 1 | | | 99 | .......... | .......... | .......... |
| 100 | | | | 1 | | | 100 | .......... | .......... | .......... |
| 101 | | | *Copper gauze* .......... | .......... | | | 101 | Nov. 20 | 16 | .......... |
| 102 | | | | | | | 102 | Nov. 11 | 7 | .......... |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 162 | Beet | Tubes, 23 by $1^{cm}$ | **Asbestus** | 1 | July 22 | | 162 | | | |
| 163 | | | | 1.4 | | | 163 | | | |
| 164 | | | **Sand 20° to 30°** | 0.3 | | | 164 | | | |
| 165 | | | | | | | 165 | | | |
| 166 | | | **Sand 100°** | 0.7 | | | 166 | | | |
| 167 | | | | 0.3 | | | 167 | | | |
| 168 | Beet | Tubes, 23 by $1^{cm}$ | *Open* | | July 22 | | 168 | July 25 | 3 | |
| 169 | | | | | | | 169 | July 27 | Less than 5 | |
| 170 | | | *Copper gauze* | | | | 170 | July 24 | 2 | |
| 171 | | | | | | | 171 | July 28 | 6 | |
| 172 | Beet | Flasks, $100^{cm^3}$ | *Open* | | July 22 | | 172 | July 24 | 2 | |
| 173 | | | *Copper gauze* | | | | 173 | July 24 | 2 | |

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[a] No. 12 was exposed for twenty minutes on the 17th instant without becoming infected, but decomposed in about two and one-half days after the exposure of nine hours on the 23d instant. No. 13 began to decompose within one day after the exposure of twenty-four hours on the 25th instant. The filters were freshly ignited before being replaced. In Nos. 12 to 14 the necks of the tubes were plugged with asbestus; in all the other tubes employed, disks of copper gauze, ordinarily of eighty meshes to the inch, were fitted into the necks, and were covered with a thin layer of sand, of 25° to 30°, whenever very fine filtering media were employed.

[b] In No. 20 the sand barely covered the copper gauze above the edges, and a small quantity *from the upper layers* gradually worked its way down behind the gauze into the infusion, carrying germs with it.

[c] No. 26. Pieces of copper gauze were added to the infusion to see whether the copper salts formed would affect the development of germs. (See Nos. 1 to 4, second series, Table I.)

[d] The filters in tubes 35 to 58, inclusive, were not heated or sterilized in any way.

[e] No. 103 showed the first indications of souring on the 2d instant; separation of caseine took place very slowly.

[f] No. 105 was not boiled until noon, and had just begun to turn, showing slight acid reaction. It was boiled in a paraffin bath for over an hour, the temperature of the bath being about 110°. Coagulated rapidly, and subsequently putrefied.

[g] No. 106 was not boiled, and had soured completely by 3.30 p. m. Temperature 30° C.

[h] Putrefied.

[i] The flasks were boiled in a paraffin bath for a long time, at temperatures ranging from 101° to 110°. Nos. 107–109, and 113 and 114 remained for several months apparently unchanged. Caseine separated in very small amounts in granular masses, which for the most part remained suspended in the milk. The separation proceeded so slowly that no date of incipient decomposition could be assigned. Nos. 107 and 113 opened on January 22 gave acid reaction and a peculiar odor resembling that of unsalted butter which has stood for a long time. Under the microscope (Zeiss, $\frac{1}{18}$ homogeneous oil-immersion), spherical cells, resembling colostrum corpuscles, which are stained by aniline-violet were observed. No bacterial growths could be found in any portions. No. 105 contained the same spherical cells in addition to bacterial forms. Nos. 108 and 109 were not examined microscopically. No. 112, examined under the microscope (Hartnack, nine, water-im. objective), December 18, was found to contain living bacteria in great abundance. The caseine separated out very rapidly after the first indications of souring. No. 114, as also Nos. 108 and 109, opened February 11, gave same oily odor, &c., as Nos. 107 and 113. No bacteria could be found in No. 114 (Hartnack, nine, water-im. objective). Contained spherical cells similar to those in Nos. 107 and 113.

[j] Case similar to No. 20.

[k] Cases similar to Nos. 20 and 124.

NOTE.—A large number of infusions of beef, hay, fish, cucumber, and beet, exposed in test-tubes, flasks, and capsules in different parts of the laboratory for comparison with these, broke down within *thirty hours;* some within *twenty-four hours.* None remained clear over thirty hours.

## FIRST SERIES OF EXPERIMENTS—Continued.

### AIR-FILTRATIONS—Continued.

### TABLE I.—*Dry Filters*—Continued.

| No. | Infusion. | Dimensions of tubes, &c., employed. | Filters. | | Date of experiment. | Subsequent treatment. | No. | Date of decomposition. | Time in— | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Kind. | Length in centimeters. | | | | | Days. | Hours. |
| 138 | Fish | Tubes, 23 by 1cm | Asbestus | 1.3 | July 15 | .......... | 138 | .......... | .......... | .......... |
| 139 | | | | 1 | | | 139 | .......... | .......... | .......... |
| 140 | | | Sand 30° to 50° | 0.2 | | | 140 | .......... | .......... | .......... |
| 141 | | | | 0.1 | | | 141 | .......... | .......... | .......... |
| 142 | | | Sand 100° | 0.5 | | | 142 | .......... | .......... | .......... |
| 143 | | | | 0.8 | | | 143 | .......... | .......... | .......... |
| 144 | | | *Open* | .......... | | | 144 | July 20 | 5 | .......... |
| 145 | | | *Copper gauze* | .......... | | | 145 | July 21 | 6 | .......... |
| 146 | | | | | | | 146 | July 29 | 14 | .......... |
| 147 | Cucumber | Flasks, 200cm | Asbestus | 5 | July 22 | .......... | 147 | .......... | .......... | .......... |
| 148 | | | | | | | 148 | .......... | .......... | .......... |
| 149 | Cucumber | Tubes, 23 by 1cm | Asbestus | 0.8 | July 22 | .......... | 149 | .......... | .......... | .......... |
| 150 | | | | | | | 150 | .......... | .......... | .......... |
| 151 | | | Sand 30° to 50° | 0.1 | | | 151 | Dec. 15 | 146 | .......... |
| 152 | | | | 0.2 | | | 152 | .......... | .......... | .......... |
| 153*k* | | | Sand 100° | *k* | | | 153*k* | Nov. 24 | 125*k* | .......... |
| 154*k* | | | | | | | 154*k* | Oct. 18 | 88*k* | .......... |
| 155 | | | *Open* | .......... | | | 155 | July 23 | 1 | 9 |
| 156 | | | | | | | 156 | July 24 | 2 | .......... |
| 157 | | | *Copper gauze* | .......... | | | 157 | July 24 | 2 | .......... |
| 158 | | | | | | | 158 | July 25 | 3 | .......... |
| 159 | Cucumber | Flasks, 100cm | *Open* | .......... | July 22 | .......... | 159 | July 23 | .......... | Less than 21. |
| 160 | | | *Copper gauze* | | | | 160 | July 23 | .......... | |
| 161 | Beet | Flask, 200cm3 | Asbestus | 5 | July 22 | .......... | 161 | .......... | .......... | .......... |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 24 | ........ | Flask, 100$^{\mathrm{cm}^3}$ ........ | **Asbestus (packed)**........ | 5 | July 15 | | 24 | ........ | ........ | ........ |
| 25 | Fish ........ | Tubes, 46 by 2$^{\mathrm{cm}}$..... | **30° to 50°.. Sand** ...... | 10 | | | 25 | Bet. Sept. 25 and Oct. 13. | **Not known; more than 72 days, less than 90 days.** | |
| 26 | | | **100°** ....... | | | | 26 | ........ | ........ | ........ |
| 27 | Cucumber ..... (See note *e*.) | Flasks, 100$^{\mathrm{cm}^3}$ ....... | **Asbestus (packed)** ....... | 4 | July 22 | | 27 | ........ | ........ | ........ |
| 28 | | | | | | | 28 | ........ | ........ | ........ |
| 29 | | | **Sand, 30° to 50°**......... | | | | 29 | ........ | ........ | ........ |
| 30 | | | | | | | 30 | ........ | ........ | ........ |
| 31 | | | **Sand, 100°** .............. | | | | 31 | ........ | ........ | ........ |
| 32 | | | | | | | 32 | ........ | ........ | ........ |
| 33 | Beet ........... (See note *e*.) | Flasks, 100$^{\mathrm{cm}^3}$ ....... | **Asbestus (packed)** ....... | 4 | July 22 | | 33 | ........ | ........ | ........ |
| 34 | | | | | | | 34 | ........ | ........ | ........ |
| 35 | | | **Sand, 30° to 50°**......... | | | | 35 | ........ | ........ | ........ |
| 36 | | | | | | | 36 | ........ | ........ | ........ |
| 37 | | | **Sand, 100°**.............. | | | | 37 | ........ | ........ | ........ |
| 38 | | | | | | | 38 | ........ | ........ | ........ |

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[a] Water filtered through No. 3 on the 23d of August, too large a quantity having been added to supply the loss by evaporation. The infusion broke down within twenty-four hours. The decompositions in Nos. 1 and 4 were likewise probably due to infiltration of unsterilized water.

[b] No. 9 was boiled after the addition of asbestus until the asbestus was thoroughly moistened by the condensed vapors.

[c] The tubes were all clear on the 3d instant, and were not examined again until the 7th instant, when a fungoid growth was found in No. 20. The hay infusions in this tube and in No. 23 were probably not completely sterilized by boiling.

[d] No. 21 was boiled until the asbestus was completely saturated with moisture.

[e] No subsequent additions of water to the filters of the cucumber and beet infusions.

## FIRST SERIES OF EXPERIMENTS—Continued.

### AIR-FILTRATIONS—Continued.

### TABLE II.—*Wet filters.*

| No. | Infusion. | Dimensions of tubes, &c., employed. | Filters. |  | Date of experiment. | Subsequent treatment. | No. | Date of decomposition. | Time in— |  |
|---|---|---|---|---|---|---|---|---|---|---|
|  |  |  | Kind. | Length in centimeters. |  |  |  |  | Days. | Hours. |
| 1a | Beef | Tubes, 46 by $2^{cm}$ (See figure 1.) | Sand, 25° to 40° | 17 | June 18 | Water which had been exposed to the air for some time was added to the tubes on the 19th, 20th, 21st, and 22d insts. A few drops filtered through Nos. 1 and 4 each time. Unsterilized water was subsequently added to Nos. 2 and 3 from time to time in sufficient quantity to keep the filters saturated with moisture, but not to run through into the infusions. Nos. 2, 5 to 8, 10, 13 to 19, 25, and 26 were kept saturated with water for a long time, and then kept moist. | 1a | June 23 | 5a | .......... |
| 2 |  |  |  | 7 |  |  | 2 | .......... | .......... | .......... |
| 3a |  |  | Sand, 100° | 17 |  |  | 3a | Aug. 24 | 67a | .......... |
| 4a |  |  |  | 7 |  |  | 4a | June 23 | 5a | .......... |
| 5 |  |  | Sand, 25° to 40° | 17 | June 26 |  | 5 | .......... | .......... | .......... |
| 6 |  |  |  | 7 |  |  | 6 | .......... | .......... | .......... |
| 7 |  |  | Sand, 100° | 17 |  |  | 7 | .......... | .......... | .......... |
| 8 |  |  |  | 7 |  |  | 8 | .......... | .......... | .......... |
| 9b | Beef | Flask, $200^{cm^3}$ | Asbestus | 1.5 | June 29 |  | 9b | .......... | .......... | .......... |
| 10 | Beef | Tube, 46 by $2^{cm}$ | Finely-pulverized charcoal. | 15 | Aug. 8 |  | 10 | .......... | .......... | .......... |
| 11 | Beef | Flasks, $200^{cm^3}$ | Animal charcoal, mostly 15°. | 5 | Aug. 28 |  | 11 | Sept. 7 | 10 | .......... |
| 12 |  |  |  |  |  |  | 12 | Sept. 18 | 21 | .......... |
| 13 | Beef | Tubes, 46 by $2^{cm}$ | Loess | 15 | Nov. 4 |  | 13 | .......... | .......... | .......... |
| 14 |  |  |  |  |  |  | 14 | .......... | .......... | .......... |
| 15 |  |  |  | 7 |  |  | 15 | .......... | .......... | .......... |
| 16 |  |  |  |  |  |  | 16 | .......... | .......... | .......... |
| 17 | Hay | Tubes, 46 by $2^{cm}$ | Sand, 30° to 50° | 15 | July 1 |  | 17 | .......... | .......... | .......... |
| 18 |  |  |  | 7 |  |  | 18 | .......... | .......... | .......... |
| 19 |  |  | Sand, 100° | 15 |  |  | 19 | .......... | .......... | .......... |
| 20c |  |  |  | 7 |  |  | 20c | Between July 3 and 7. | Not known; 6 days at the most.c |  |
| 21d | Hay | Flasks, $200^{cm^3}$ | Asbestus (very loosely filled). | 2 | July 1 |  | 21d | .......... | .......... | .......... |
| 22 |  |  |  | 2 | July 2 |  | 22 | Dec. 18 | 164 | .......... |
| 23c |  |  |  |  |  |  | 23c | July 7 | 5c | .......... |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 24 | .................. | Flask, 100$^{\text{cm}^3}$ ........ | Asbestus (packed) ........ | 5 | July 15 | 24 | .......... | .......... | .......... |
| 25 | Fish .......... | Tubes, 46 by 2$^{\text{cm}}$ ..... | 30° to 50° .. Sand ...... | 10 | | 25 | Bet. Sept. 25 and Oct. 18. | Not known; more than 72 days, less than 90 days. | |
| 26 | | | 100° ....... Sand ...... | | | 26 | .......... | .......... | .......... |
| 27 | Cucumber ..... (See note *e*.) | Flasks, 100$^{\text{cm}^3}$ ....... | Asbestus (packed) ....... | 4 | July 22 | 27 | .......... | .......... | .......... |
| 28 | | | | | | 28 | .......... | .......... | .......... |
| 29 | | | Sand, 30° to 50° ......... | | | 29 | .......... | .......... | .......... |
| 30 | | | | | | 30 | .......... | .......... | .......... |
| 31 | | | Sand, 100° .............. | | | 31 | .......... | .......... | .......... |
| 32 | | | | | | 32 | .......... | .......... | .......... |
| 33 | Beet ........... (See note *e*.) | Flasks, 100$^{\text{cm}^3}$ ....... | Asbestus (packed) ....... | 4 | July 22 | 33 | .......... | .......... | .......... |
| 34 | | | | | | 34 | .......... | .......... | .......... |
| 35 | | | Sand, 30° to 50° ......... | | | 35 | .......... | .......... | .......... |
| 36 | | | | | | 36 | .......... | .......... | .......... |
| 37 | | | Sand, 100° ............... | | | 37 | .......... | .......... | .......... |
| 38 | | | | | | 38 | .......... | .......... | .......... |

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[a] Water filtered through No. 3 on the 23d of August, too large a quantity having been added to supply the loss by evaporation. The infusion broke down within twenty-four hours. The decompositions in Nos. 1 and 4 were likewise probably due to infiltration of unsterilized water.

[b] No. 9 was boiled after the addition of asbestus until the asbestus was thoroughly moistened by the condensed vapors.

[c] The tubes were all clear on the 3d instant, and were not examined again until the 7th instant, when a fungoid growth was found in No. 20. The hay infusions in this tube and in No. 23 were probably not completely sterilized by boiling.

[d] No. 21 was boiled until the asbestus was completely saturated with moisture.

[e] No subsequent additions of water to the filters of the cucumber and beet infusions.

TABLE III.—*Slow filtrations.*

| No. | Infusion. | Dimensions of tubes, &c., employed.* | Filters. | | Date of experiment. | Subsequent treatment. | No. | Date of decomposition. | No. of liters of air filtered, up to date of decomposition. |
|---|---|---|---|---|---|---|---|---|---|
| | | | Kind. | Length in centimeters. | | | | | |
| 1*a* | Beef ........... | Flask, $500^{cm^3}$ ...... (See figure 2.) | **Asbestus**.............. | 5 | June 19 | Filtration maintained almost constantly, day and night, from June 21 until September 12, inclusive, with the exceptions of July 4, 5, 6, 18, and 19, and August 22 and 23. | 1*a* | Sept. 12 | **89 liters.** |
| 2*b* | Beef ........... | Flask, $500^{cm^3}$ ...... | **Sand, 100°**............ | 12 | June 25 | Constantly, from June 25 to July 8 ........ | 2*b* | See *note b.* | *About* 14 *liters. See note b.* |
| 3 | Beef ........... | Flask, $500^{cm^3}$ ...... | **Sand, 25° to 40°**...... | 14 | June 26 | As the aspiration was not perfectly regular, the apparatus was tested for rapid filtrations under the filter-pump. June 28, aspirated under half-pressure for 5 minutes; June 29, full pressure for over 20 minutes; and July 2, full pressure for 2 hours. | 3 | Between July 8 and 9. | **Not known.** |
| 4 | Beef ........... (See note *c*.) | Flask, 1 L........ | **Sand, 30° to 40°**...... | 10 | July 17 | No. 4 constantly, day and night, from July 20 to September 23, inclusive, excepting August 22, 23, and 30, and September 18, 19, and 20; and from October 18 to December 17, inclusive, excepting December 4 to 7, inclusive. | 4 | .......... | **434 liters, up to date. Infusion still fresh. See note *c*.** |
| 5 | | | **Sand, 50° to 60°**...... | | | No. 5 constantly, from July 20 to September 23, inclusive, excepting August 22, 23, and 30, and September 18, 19, and 20; and from October 18 to November 2. | 5 | Nov. 2 | 258 *liters. See note c.* |
| 6 | | | **Sand, 100°**............ | | | No. 6 constantly, from July 20 to July 26, inclusive. | 6 | July 27 | 5 *liters after saturation of the filter by the infusion. See note c.* |
| 7*d* | Beef ........... | Flask, 1 L......... | **Charcoal, 25° to 50°**.. | 10 | Oct. 23 | Constantly, from October 26 to December 3, inclusive, and from December 8 to December 17, inclusive. | 7*d* | .......... | **190 liters, up to date. Infusion still fresh. See note *d*.** |

## FIRST SERIES OF EXPERIMENTS—Continued.

### QUANTITATIVE AIR-FILTRATIONS—Continued.

### TABLE III.—*Slow filtrations*

| No. | Infusion. | Dimensions of tubes, &c., employed. | Filters. |  | Date of experiment. | Subsequent treatment. | No. | Date of decomposition. | No. of liters of air filtered, up to date of decomposition. |
|---|---|---|---|---|---|---|---|---|---|
|  |  |  | Kind. | Length in centimeters. |  |  |  |  |  |
| 8e | Beef ........... | Flask, 1 L......... | Animal charcoal, 20° to 100°. | 10 | Oct. 30 | Constantly, from October 31 to December 3, inclusive, and from December 8 to December 17, inclusive. | 8e | .......... | 180 liters, up to date. Infusion still fresh. See note e. |

*a* The filtration was carried on 76 days, averaging about $1,171^{\mathrm{cm}^3}$ per day. The filtration averaged about 2 liters per day for the first month, but was afterwards necessarily carried on somewhat more slowly on account of the persistency of the air bubbles.

*b* Flask broken on the 7th of July.

*c* In Nos. 4 and 5 the infusions were occasionally sucked back into the filter-tubes, though without moistening the entire contents of the filters. In No. 5 the infusion ran back into the filter twice during the last week of October, and the upper portions of the sand were found on November 2 to be slightly moistened. In No. 6 the infusion ran back into the filter July 22 and was carried up through the sand column by capillary action, moistening it throughout. Undoubtedly the decomposition spread downwards through this tube and infected the infusion in the flask. The filtration of No. 4 has been carried on 116 days, up to date, averaging $3,655^{\mathrm{cm}^3}$ per day. The filtration of No. 5 was carried on 75 days, averaging $3,444^{\mathrm{cm}^3}$ per day.

*d* The filtration has been carried on 49 days, up to date, averaging about $3,878^{\mathrm{cm}^3}$ per day.

*e* In No. 8 the infusion was forced back into the filter, completely saturating it, November 28. The filtration has been carried on 44 days, up to date, averaging about $4,091^{\mathrm{cm}^3}$ per day.

* The inner diameter of the filter-tubes was in all cases $1^{\mathrm{cm}}$.

*Table IV, first series—Dry filters. Quantitative, rapid air-filtrations.*

Tubes as shown in Fig. 3, were employed for these filtrations, and were filled in the
me manner as those in Table I. The aspirations were in all cases through the same
m of the tubes, though both necessarily contained filters.

Three tubes of this series (Nos. 3, 8, and 14) were not completely sterilized when
repared, and two of them (Nos. 8 and 14) were consequently boiled again. In No. 1
ubbles were forced up into the filter, in consequence of the rapidity of a filtration,
d decomposition ensued, as it almost invariably does in such cases, in consequence
direct infection down the tube. The tubes 1.3$^{cm}$ in diameter were found to be too
arrow for the subsequent, more rapid filtrations, and only those 1.9$^{cm}$ in diameter
ere therefore tested. The filtrations with the narrow tubes are consequently not
corded in the table below.

Most of the wide tubes have been tested many times, ***but in not a single instance as***
***t has the filter failed to remove the germs from the air passing through it, though the filtra-***
***ns have finally been carried on with very great rapidity,*** as will be seen by an examina-
on of the tables.

We purpose to continue increasing the rate of these filtrations until the infusions
nally break down, *i. e.*, until the air is forced through the filters in such a current
at the germs are carried with it; though, in view of the surprising filtering pow-
s of the materials employed, it may first be necessary to modify our apparatus.

## FIRST SERIES OF EXPERIMENTS—Continued.

### QUANTITATIVE AIR-FILTRATIONS—Continued.

### TABLE IV.—*Rapid filtrations.*

[Filtrations of air, at intervals, beginning at rates of 1 *liter* in 3 to 7½ *hours*, and increasing to rates of 1 *liter* per 2½ to 1¼ *minutes*.]

| No. | Infusion. | Dimensions of tubes, &c., employed. | Filters. Kind. | Filters. Length in centimeters. | Date of experiment. | Subsequent treatment. | No. | Date of decomposition. | Time in— Days. | Time in— Hours. |
|---|---|---|---|---|---|---|---|---|---|---|
| 1a | Beef | U-tubes, 32 by $1.3^{\mathrm{cm}}$, inner diameter. (See Fig. 3.) | Asbestus | 17 | June 19 | For dates and rates of filtration, see below. | 1a | July 22 | 10 *from time of saturation.* | |
| 2 | | | | | | | 2 | | | |
| 3b | | | Sand, 25° to 30° | 11 | | | 3b | June 23 | 4b | |
| 4 | | | | 6 | | | 4 | | | |
| 5 | | | Sand, 100° | 11 | | | 5 | | | |
| 6 | | | | 6 | | | 6 | | | |
| 7 | Hay | U-tubes. Nos. 7, 9, and 11, 46 by $1.3^{\mathrm{cm}}$, inner diameter; Nos. 8, 10, and 12, 32 by $1{\cdot}9^{\mathrm{cm}}$. | Asbestus (packed) | 24 | July 1 | do | 7 | | | |
| 8c | | | | 10 | | | 8c | July 7 | 6c | |
| 9 | | | Sand, 30° to 50° | 24 | | | 9 | | | |
| 10 | | | | 10 | | | 10 | | | |
| 11 | | | Sand, 100° | 23 | | | 11 | | | |
| 12 | | | | 9 | | | 12 | | | |
| 13 | Fish | U-tubes. Nos. 13, 15, and 17, 46 by $1.3^{\mathrm{cm}}$; Nos. 14, 16, and 18, 32 by $1{\cdot}9^{\mathrm{cm}}$. | Asbestus (packed) | 25 | July 15 | do | 13 | | | |
| 14d | | | | 10 | | | 14d | July 19 | 4d | |
| 15 | | | Sand, 30° to 50° | 25 | | | 15 | | | |
| 16 | | | | 10 | | | 16 | | | |
| 17 | | | Sand, 100° | 25 | | | 17 | | | |
| 18 | | | | 10 | | | 18 | | | |
| 19 | Cucumber | U-tubes, 31 by $1.0^{\mathrm{cm}}$ | Asbestus (packed) | 10 | July 23 | do | 19 | | | |
| 20 | | | Sand, 30° to 50° | | | | 20 | | | |
| 21 | | | Sand, 100° | | | | 21 | | | |
| 22 | Beet | U-tubes, 42 by $1.9^{\mathrm{cm}}$ | Asbestus (packed) | 10 | July 23 | do | 22 | | | |
| 23 | | | Sand, 30° to 50° | | | | 23 | | | |
| 24 | | | Sand, 100° | | | | 24 | | | |

DATES OF FILTRATION.*

| No. | Infusion. | Rates of filtrations of two liters of air. | | | | | | | | | | | | | | | | | | | | | | | | No. | Infusion. | Rates of filtrations of one liter of air. | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | July. | | | | | | | | | | | | | | | | | | | | | | | | | | October. | | | | November. | | | |
| | | 3 | | 7 | | 9 | | 12 | | 14 | | 14 | | 17 | | 20 | | 26 | | 27 | | 29 | | 30 | | | | 25 | | 26 | | 1 | | 29 | |
| | | H. | M. | H. | M. | H. | M. | H. | M. | H. | M. | H. | M. | H. | M. | H. | M. | H. | M. | H. | M. | H. | M. | H. | M. | | | H. | M. | H. | M. | H. | M. | H. | M. |
| 8 | Hay ... | 15 | 0 | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | 0 | 45 | .... | .... | .... | .... | 2 | 0 | 8 | Hay ... | 0<br>0 | 12<br>22 | .... | .... | 0 | 6 | 0 | 1½ |
| 10 | | 12 | 0 | 8 | 0 | 4 | 0 | 2 | 0 | 1 | 40 | 1 | 15 | 1 | 15 | 0 | 55 | 0 | 38 | .... | .... | .... | .... | 0 | 30 | 10 | | .... | .... | 0 | 4 | 0 | 3 | 0 | 1½ |
| 12 | | 12 | 0 | 8 | 0 | 4 | 30 | 1 | 50 | 1 | 40 | 1 | 15 | 1 | 15 | 0 | 50 | 0 | 45 | .... | .... | .... | .... | 0 | 30 | 12 | | .... | .... | 0 | 11 | 0 | 9½ | 0 | 2 |
| 14 | Fish ... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | 3 | 0 | .... | .... | 0 | 35 | 14 | Fish ... | 0 | 12 | .... | .... | 0 | 10 | 0 | 2½ |
| 16 | | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | 8 | 30 | .... | .... | 2 | 30 | .... | .... | 2 | 0 | 16 | | .... | .... | .... | .... | .... | .... | .... | .... |
| 18 | | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | 8 | 30 | .... | .... | 2 | 30 | .... | .... | 2 | 0 | 18 | | .... | .... | .... | .... | .... | .... | .... | .... |
| 19 | Cucumber. | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | 0 | 50 | .... | .... | 19 | Cucumber. | 0 | 9 | .... | .... | 0 | 8 | 0 | 2 |
| 20 | | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | 0 | 45 | .... | .... | 20 | | .... | .... | 0 | 9 | 0 | 4 | 0 | 1½ |
| 21 | | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | 0 | 45 | .... | .... | 21 | | .... | .... | 0 | 9 | 0 | 3 | 0 | 2 |
| 22 | Beet ... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | 0 | 50 | .... | .... | 22 | Beet ... | 0 | 13 | .... | .... | 0 | 6 | 0 | 2 |
| 23 | | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | 0 | 50 | .... | .... | 23 | | .... | .... | 0 | 10 | 0 | 5 | 0 | 1½ |
| 24 | | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | 0 | 50 | .... | .... | 24 | | .... | .... | 0 | 9½ | 0 | 4 | 0 | 2 |

[a] The tubes were found to be too narrow for rapid filtrations, as the bubbles did not break readily. In No. 1, bubbles were carried up into the filter July 12, moistening it throughout with the infusion. The infusion decomposed at the surface, and decomposition spread downwards, infecting the infusion in the tube.

[b] Infusion probably not completely sterilized.

[c] No. 8 was probably not sterilized when filled. The infusion was boiled again in the tube July 17 to destroy the living organisms.

[d] No. 14 was not sterilized when filled, as it began to break down before being tested as a filter. The infusion was boiled again in the tube, July 21, to destroy the growths.

* The filtration of Nos. 1–6, 7, 9, 11, 13, 15, 17 are omitted from this table, as very rapid filtrations could not be carried on in these narrow ($1.8^{\mathrm{cm}}$) tubes. The filtrations of *two* liters of air ranged from *fifteen hours to thirty-five minutes*. As the tubes would not admit of more rapid filtrations, the infusions being sucked up into the filters, subsequent filtrations of *one* liter of air were not attempted.

All of these experiments are to be tried with the remaining artificial filters—as spongy iron, carferal, &c.—which have not as yet been tested, and also with a large number and variety of natural soils and with still coarser sands and gravels; the quantitative filtrations, besides being continued with dry filters, are to be tried with sterilized wet filters, with unsterilized dry filters, and with filters moistened with unsterilized water, putrid infusions, &c.

The question of temperature is furthermore to be more fully taken into consideration, as this is perhaps a not unimportant factor in experiments of this nature, and some of the tests are to be made at temperatures of 35° to 50° or 60°, *i. e.*, at temperatures considerably above the average temperature of the air in summer.

### SECOND SERIES OF EXPERIMENTS—LIQUID-FILTRATIONS.

*Tables I and II—Filtrations of fresh and putrid infusions through sterilized filters.*

For all of these experiments, excepting No. 5 of each table, tubes, as shown in Fig. 1, were employed. The tubes were strongly heated, filled with the hot sterilized filters, as before described, and then heated again in a Carius oven for several hours at a temperature of 250° to 275°, or, in a few cases, on a combustion-furnace at a low red heat. The flasks and filter-tubes used in experiment 5 of each table were very strongly heated over the naked flame of a large burner. After the tubes had cooled the infusions were slowly added. The fresh infusions were previously exposed to the air in capsules (see notes accompanying the tables) for a sufficient length of time to insure their containing germs.

As the filtrations into the tubes necessarily took place against the pressure of the air within the tubes, the air being forced out through the mass of the filters, they proceeded very slowly in most cases. As the object was, however, to determine whether the materials employed could, under the most favorable circumstances, act as filters, which at first seemed highly improbable, as the germs would naturally be expected to adhere somewhat tenaciously to the particles of a liquid, this was considered to be an advantage rather than an obstacle to the experiments. The simple devices resorted to in various cases to slightly hasten the filtrations, and to prevent the air from raising the mass of the filters, are described in the tables.

How very difficult it is to remove the germs from a flowing liquid, by means of a filter, is abundantly shown in the experiments of this series, many of the materials which afforded the infusions ample protection from the air failing here utterly to prevent the transmission of germs. Thus the sands, the vegetable charcoals, coarse animal charcoal, and likewise asbestus in most cases, did not in these tests act as filters for fresh-beef infusions; and sand, vegetable charcoal, and coarse animal charcoal failed even to filter putrid-beef infusions clear, the first few drops percolating them being almost invariably still cloudy from the bacterial growths, and continuing to decompose. The only exception to this is experiment No. 4, but only a drop or two of the infusion had filtered here.

On the other hand there are two (Nos. 13 and 14) and in all probability four (Nos. 12 to 14 and 30, Table I), cases of successful filtration of a fresh-beef infusion through tightly-packed asbestus, which likewise removed both the products of germination and the undeveloped germs * themselves from a putrid-beef and hay infusion in the only two cases (Nos. 6 and 12, Table II) in which it was tried.

Very fine animal charcoal (experiments 25–28, Table I) likewise served probably in every case to filter the infusions.† It is true that three of these filtered infusions subsequently decomposed, but the time required leaves no room for doubt that the cause was due to direct inoculation. The tubes were not sealed at the necks after the filtrations, as it seemed of interest to determine whether bacterial growths could spread through the fine charcoal filters, as they had previously done in a few instances in the first series of experiments through asbestus and sand filters, which had accidentally become permeated by the infusions, and, if so, to learn how long a time might be required for the infection to spread through the filters and down the films of liquid on the sides of the tubes into the filtered infusions. After the decompositions of Nos. 25, 26, and 28, which occurred in forty-five, forty-eight, and fifty-one days, respectively, No. 27 was, however, sealed. This has remained fresh.

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* It may be argued that the evidence of perfect filtration in these two experiments is not conclusive so far as the undeveloped organisms are concerned, for, although the putrid infusions filtered clear, and have since remained perfectly limpid for seven months, yet there is a remote possibility that their nutritive matters for the forms of organism which they contained may have become exhausted prior to the filtrations. Under such a contingency the filtered infusions may have retained germs, which, however, have subsequently not developed from simple lack of nourishment. We shall decide this by inoculation tests on other cultivating liquids, as well as by determining whether the infusions are still capable of nourishing the same forms of organisms as before.

† As the filtrations were carried on in these experiments for three to four days, they are in reality tests both of fresh and putrid infusions.

In most of the cases of decomposition recorded in Table I the development of life was sufficiently rapid to be detected in from one to three days, and in a few cases even within a few hours after the filtrations. Several infusions (especially Nos. 3 and 4, 11, and 42), however, remained perfectly clear for a somewhat longer period. It is not impossible in these cases that the infusions were subsequently infected, as in the instances previously cited. It is, however, more probable that the fine sand and the asbestus acted here as differential filters, though failing to completely remove the germs.

It must here be remembered that the dates of decomposition given in these tables denote the times when the first appearance of an organic growth of any kind was observed, either through the appearance of a fungus in any part of the infusion, or, as was more frequently the case in these filtrations, through the detection of the first faint opalescent cloudiness of the liquid, so characteristic of some forms of bacterial developments, or, again, of a minute film on the tube around the edges of the infusion.

Whenever there could be any doubt in regard to the decomposition of the infusions recourse was had to the microscope, the examinations being made in most instances with a Zeiss, twelfth, homogeneous oil-immersion objective. A number of the infusions which had manifestly broken down were also examined microscopically, but as the object of our investigations was simply to determine in general whether the fungi and their germs were filtered out from the infusions, the microscopic examinations are not given in the tables. It is, however, perhaps worthy of note that while in all cases the ordinary bacteria of putrefaction (*B. termo*) and likewise *B. lineola* were present in decomposing infusions, *bacillæ* forms were very rarely met with, though the latter were almost invariably found in the water-filtrations of Table III, a fact which would appear to indicate a comparative freedom of the atmosphere in this locality from germs of this class.

That the filtered infusions should have decomposed somewhat more slowly than the corresponding unfiltered portions, which were left exposed for comparison, and which were constantly receiving fresh accessions of germs from the surrounding atmosphere, is natural, and it is certainly possible that if the greater portion of the germs be removed by a filtration the decomposition may proceed so slowly as to require several days for its detection.

It is, however, clear from the experiments that only asbestus and fine animal charcoal of the filters as yet tried have the power of filtering these infusions. With these we shall try several more filtrations, sealing the tubes subsequent to the experiment.

## SECOND SERIES OF EXPERIMENTS.

### LIQUID-FILTRATIONS.

TABLE I.—*Filtrations of various fresh, unsterilized infusions through sterilized filters.*

| No. | Infusion. | Dimensions of tubes, &c., employed. | Filters. | | Date of experiment. | Subsequent treatment. | No. | Date of decomposition. | Time in— | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Kind. | Length in centimeters. | | | | | Days. | Hours. |
| 1<br>2 | Beef (See notes *a*, *d*.) | Tubes, 46 by $2^{cm}$ | **Sand, 25° to 40°** | 16 | June 19 | | 1<br>2 | June 24 | 5 | |
| 3<br>4 | | | **Sand, 100°** | | | | 3<br>4 | July 1 | 12 | |
| 5*a*, *b* | Beef | Flask, $250^{cm3}$ | **Sand, 100°** | 45 | June 23 | | 5 | June 24 | 1 | |
| 6<br>7 | Beef (See notes *a*, *c*.) | Tubes, 46 by $2^{cm}$ | **Sand, 25° to 40°** | 15 | June 26 | | 6<br>7 | June 27 | 1 | |
| 8<br>9 | Beef (See notes *a*, *c*, *d*.) | Tubes, 46 by $2^{cm}$ | **Sand, 25° to 40°** | 15 | June 28 | | 8<br>9 | June 30<br>June 29 | 2<br>1 | |
| 10 | Beef | Tube, 46 by $2^{cm}$ | **Asbestus (tightly packed).** | 15 | July 9 | No. 10 was warmed slightly on the 9th and 10th instants, several times, to hasten the filtration. | 10 | July 13 | 4 | |
| 11<br>12 | Beef (See note *c*.) | Tubes, 46 by $2^{cm}$ | **Asbestus (tightly packed).** | 15 | July 24 | Tubes 11 and 12 were gently warmed several times, but the filtration was not carried on so rapidly as in the previous case. | 11<br>12 | Aug. 4<br>Aug. 29 | 11<br>36 | |
| 13<br>14 | Beef (See note *c*.) | Tubes, 46 by $2^{cm}$ | **Asbestus (tightly packed).** | 15 | July 31 | Tubes 13 and 14 were sealed at the necks August 2. | 13<br>14 | | **Still fresh.** | |
| 15<br>16 | Beef (See note *c*.) | Tubes, 46 by $2^{cm}$ | **Charcoal, 30° to 100°** | 15 | Aug. 4 | | 15<br>16 | Aug. 6<br>Aug. 8 | 2<br>4 | |
| 17<br>18<br>19<br>20 | Beef (See note *c*.) | Tubes, 46 by $2^{cm}$ | **Charcoal, 25° to 50°** | 15 | Sept. 1 | | 17<br>18<br>19<br>20 | Sept. 3<br>Sept. 2<br>Sept. 2<br>Sept. 2 | 2<br>1<br>1<br>1 | |
| 21<br>22<br>23<br>24 | | | **Animal charcoal, coarse and fine, mostly 15°.** | | | Tubes 23 and 24 were sealed at the necks September 2. | 21<br>22<br>23<br>24 | Sept. 2<br>Sept. 3<br>Sept. 4<br>Sept. 4 | 1<br>2<br>3<br>3 | |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 25<br>26<br>27<br>28 | Beef ...........<br>(See note *a*.) | Tubes, 46 by 2cm ...... | **Animal charcoal, 100°** ..... | 15 | Oct. 23 | Tubes 25 to 28 were warmed several times to hasten the filtration. Tube 27 sealed at the neck December 15. | 25 | Dec. 7 | 45 | ........ |
| | | | | | | | 26 | Dec. 10 | 48 | ........ |
| | | | | | | | 27 | ............ | **Still fresh.** | |
| | | | | | | | 28 | Dec. 13 | 51 | ........ |
| 29*e* | Milk ........... | Tube, 46 by 2cm ....... | **Asbestus (packed)** .......... | 15 | July 8 | ........................................ | 29 | July 13 | 5 | ........ |
| 30*f*<br>31*f*<br>32<br>33 | Hay ...........<br>(See note *c*.) | Tubes, 46 by 2cm .... | **Tightly { Packed } .....** | 15 | July 1 | ........................................ | 30*f* | July 21 (?) | 20 (?) | ........ |
| | | | **Loosely { Asbestus } .....** | | | | 31*f* | July 6 | **5 days possibly.** | |
| | | | **Sand, 30° to 50°** ........... | | | | 32<br>33 | July 1 | ........ | 8 |
| 34 | Fish ...........<br>(See note *c*.) | Tubes, 46 by 2cm .... | **Asbestus (packed)** .......... | 15 | July 10 | Tubes 34 and 35 warmed to hasten the filtration. | 34 | July 12 | 1 | 10 |
| 35 | | | **Sand, 100°** ................... | | | | 35 | July 11 | 1 | ........ |
| 36<br>37 | | | **Asbestus (packed)** .......... | | July 14 | ........................................<br>........................................ | 36<br>37 | July 15 | 1 | 12 |
| 38*g* | | | **Asbestus** .................... | | | ........................................ | 38 | July 14 | ........ | 6 |
| 39<br>40 | Cucumber .....<br>(See note *c*.) | Tubes, 46 by 2cm ...... | **Asbestus (tightly packed)**. | 15 | July 22 | Tubes 39 and 40 warmed very gently. Filtrations carried on very slowly. | 39 | July 28 | 6 | ........ |
| | | | | | | | 40 | July 25 | 3 | ........ |
| 41<br>42 | Beet ...........<br>(See note *c*.) | Tubes, 46 by 2cm ...... | **Asbestus (tightly packed)**. | 15 | July 22 | Tubes 41 and 42 warmed very gently. Filtrations carried on very slowly. | 41 | July 29 | 7 | ........ |
| | | | | | | | 42 | Aug. 2 | 11 | ........ |

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*a* The infusions were filtered very slowly into all the tubes, but especially into Nos. 1 to 4 and 6 to 9, from one to four days being allowed for the filtration of about two inches of the infusions. Only a very small quantity of the infusion filtered through the fine sands of Nos. 3 and 4, as the tubes were not warmed. As the air of the tubes could only escape by forcing its way up through the mass of the filters, some difficulty was experienced in carrying on the filtrations through the very fine sands and charcoals, the air tending to raise the entire mass of the filters instead of slowly working its way through them in minute bubbles. The charcoal filters were accordingly forcibly pressed down by disks of copper gauze, fitted tightly into the tubes. As the infusions in Nos. 1 to 4 were slightly colored by copper salts, due to action of the infusions upon the copper gauze employed, Ex. 26, first series, Table I was made to determine whether the copper salts present had any effect in preventing the decompositions. In no cases, however, as was subsequently found, have the copper salts preserved the infusions. The infusions for Nos. 1 to 5 were exposed for several hours in evaporating-dishes to the air of a stable-loft; those for Nos. 25 to 28 were exposed over night in the laboratory, and were diluted with tap-water before the filtrations.

*b* No. 5 contained a tube 50cm by 1.5cm. Tube tightly packed with asbestus in the neck of the flask. The filtration was carried on rapidly.

*c* The infusions Nos. 6 and 7 were exposed for six hours in evaporating-dishes near old hay in a cellar. Those for Nos. 8 and 9 were exposed nine hours near old hay. Those for Nos. 10 to 24 and Nos. 30 to 38 were exposed in the laboratory over night in evaporating-dishes. Those for Nos. 39 to 42 from 9 a. m. until 6 p. m. on the 22d instant in capsules.

*d* Tubes 8 and 9 were heated on a combustion-furnace at a red heat nearly one hour. Tubes 1 to 4 were heated on a combustion-furnace ten minutes at as high a temperature as the glass would bear without softening.

*e* Filtered liquid was very thin and watery, the filter removing the greater portion of the fat and casein; evolved gas, and, upon being shaken, coagulated rapidly.

*f* No. 31 was clear on the 3d instant, and was not examined again until the 6th instant. No. 30 showed a very faint cloudiness on the 21st instant, but the traces of bacterial development were so very faint as to leave it doubtful for some time whether decomposition had actually set in or not.

*g* In No. 38 the infusion was not filtered, the tube being packed with asbestus after it was filled with the infusion, the object being to determine whether the presence of the asbestus column retarded the initiation of decomposition, affected its rate, &c.

## SECOND SERIES OF EXPERIMENTS—Continued.

### LIQUID-FILTRATIONS—Continued.

TABLE II.—*Filtrations of putrid infusions through sterilised filters.*

| No. | Infusion. | Dimensions of tubes, &c., employed. | Filters. |  | Date of experiment. | Subsequent treatment. | No. | Date of decomposition. | Time in— |  |
|---|---|---|---|---|---|---|---|---|---|---|
|  |  |  | Kind. | Length in centimeters. |  |  |  |  | Days. | Hours. |
| 1 | Beef (See note *a*.) | Tubes, 46 by $2^{cm}$ | **Sand, 25° to 40°** | 16 | June 19 | ........ | 1*a* | (See note *a*.) | 0 | 0 |
| 2 |  |  |  | 17 |  |  | 2*a* |  |  |  |
| 3 |  |  | **Sand, 100°** | 16 |  | ........ | 3*a* |  |  |  |
| 4 |  |  |  | 17 |  |  | 4 | July 7 | 19 | ...... |
| 5*b* | Beef | Flask, $250^{cm^3}$ | **Sand, 100°** | 45 | June 23 | ........ | 5*b* | (See note *b*.) | 0 | 0 |
| 6 | Beef | Tube, 46 by $2^{cm}$ | **Asbestus (tightly packed)** | 15 | July 3 | In Nos. 6 and 12 the infusions were filtered as completely as possible, and the tubes were dried just below the neck at a gentle heat to prevent subsequent infection of the filtered infusions by direct growths down the filters and sides of the tubes. | 6 | ........ | Still | fresh. |
| 7*c* | Beef | Open tube, 60 by $1.3^{cm}$ | **Asbestus (tightly packed)** | 50 | July 12 |  | 7*c* | (See note *c*.) | 0 | 0 |
| 8 | Beef (See note *d*.) | Tubes, 46 by $2^{cm}$ | **Charcoal, 25° to 50°** | 15 | Sept. 1 |  | 8*d* | (See note *d*.) | 0 |  |
| 9 |  |  |  |  |  |  | 9*d* |  |  |  |
| 10 |  |  | **Animal charcoal, coarse and fine, 15° mostly.** |  |  |  | 10*d* |  |  |  |
| 11 |  |  |  |  |  |  | 11*d* |  |  |  |
| 12 | Hay | Tube, 46 by $2^{cm}$ | **Asbestus (tightly packed)** | 15 | July 3 |  | 12 | ........ | Still | fresh. |

*a* Nos. 1, 2, and 3 could not be filtered clear and continued to decompose. Only a few drops passed No. 4, which remained clear until the 7th of July. The tubes were heated on a combustion-furnace for ten to fifteen minutes at as high a temperature as the glass would bear without softening.

*b* No 5 could not be filtered clear. Apparatus arranged as in No. 5, Table I.

*c* A very putrid infusion was filtered through No. 7 to see whether the bacteria, odor, &c., could be removed by employing a longer filtering column. The first $100^{cm^3}$ which passed the filter were clear and almost entirely devoid of odor. On standing exposed to the air decomposition set in again within sixteen hours. Subsequent portions filtered cloudy and retained more or less the putrid odor.

*d* Filtered cloudy and continued to decompose.

Beef infusions, which were muddy from bacterial developments, were employed, and a hay infusion for No. 12, which had stood for several days exposed in a capsule. A portion of No. 5 was taken for No. 6.

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*Table III, second series—Water-filtrations.*

xperiments with a few exceptions, which are specially described below, were
d precisely as were those recorded in Table I, first series, and were allowed to
sufficient length of time, usually from three to five weeks, to prove their ster-
Water was then added, which slowly percolated the filters and ran into the
ns. In most of the experiments the filtrations were carried on very gradually,
y small quantities only of water were allowed to pass the filters. The filtra-
rough the asbestus, coal-ash, and fine animal charcoal columns were, however,
conducted much more rapidly, the tubes being occasionally gently warmed
he infusions to expel the air and hasten the flow of the liquid.

ine animal charcoal filters, as also some of the clay filters, were forcibly main-
in position in the tubes by disks of copper gauze. The loess, coal-ash, and
f the clay filters were furnished with ventilating tubes ($5^{mm}$ in diameter), which
ed through the mass of the filters to the sieves on which they rested, and pro-
for an inch or two above the tubes. These ventilating tubes were plugged at
nds with asbestus to prevent the entrance of unfiltered air; were heated for
hours in a Carius oven at a temperature of 250°, and were immediately trans-
while at this temperature to the filter-tubes, as the latter were taken from the
bath. The hot filters were then packed around them as quickly as possible,
er-tubes, as before, being very strongly heated. But very little advantage was,
er, derived from the use of these tubes, the method of employing copper disks
the filters in place, and gently warming the tubes to expel the air, being on
ole preferable.

ill be seen by a study of the table only one of the filters has served to wholly
the infusions from infection. Tightly-packed asbestus, fine animal charcoal,
rhaps, coal-ashes also have filtered the water to some extent; the first portions
the filters being probably entirely freed, and the final portions, which were
filtered, being almost entirely freed from germs, as the decompositions have
place with extreme slowness, and, in some of the experiments with asbestus
especially, are still so faintly marked as scarcely to be detected. It is possible
e loess also may have acted to a very slight degree as a differential filter, inas-
s a considerable quantity of water was filtered into these tubes before the in-
could be discerned.

ls, pure clay, mixtures of sand with clay in different proportions, vegetable
al, and coarse animal charcoal were, on the other hand, in these short columns,
y devoid of any filtering power for water, as they were before, so far as tried,
infusions themselves. Only very trifling amounts of water passed these filters
the infusions broke down; and the decompositions proceeded very rapidly, the
ns becoming thoroughly turbid in a few days, while masses of the *débris* collected
bottoms of the tubes. Nos. 32 and 40 remained clear for some time, but scarcely
reciable amount of water passed these filters.

rge number of these infusions, especially those in which the growths were feebly
d, were at different times examined microscopically. The results of these ex-
tions are given in the table.

iew of the extreme importance considered with reference to the sanitiary aspects
experiments on germ filtrations by soils possess, it was deemed advisable not
extend these tests to other natural soils, but also to continue them with sands,
ying much longer filtering columns, in order more fully to test the question
er they possess in any degree the power to act as filters. Tests with other soils
not as yet been tried to any great extent, but we are enabled in this report,
gh the experiments Nos. 2, 56, and 57, to give decisive and complete results in
r to the question so far as sand filtrations are concerned.

xperiment No. 2, a filtering column of the finest sand, a little over four feet in
n, was employed. The glass filter-tube was heated, then filled with very hot sand,
eated again very intensely throughout its entire length. After cooling suffici-
it was attached to the flask containing the infusion, which was then boiled for
n hour to insure its absolute sterility. The rubber stopper through which the
tube passed was provided with a second, short tube filled with asbestus, which
hed an escape for the steam during the boiling and for the air during the filtra-
This asbestus tube, as were those used in all subsequent experiments, was care-
sterilized. Freshly-ignited asbestus was packed into the heated tubes, and the
precautions were observed to thoroughly heat all the utensils employed in the
ions.

xperiments Nos. 56 and 57 lead pipes were used, the filtering columns of mixed
and fine sand (18° to 100°) being 22 and 100 feet in length, respectively. (Fig.
s the arrangement of the apparatus.)

sand was heated in a large boiler for a long time, the boiler being maintained
ll red-heat, and was then poured into the pipes while still intensely hot. The
closed at the lower ends, were suspended perpendicularly during this process,

and the sand was filled in as compactly as possible. The longer pipe was filled in two lengths, which were afterwards soldered together. The pipes were then coiled, disks of copper gauze were fitted into the lower ends to prevent the sands from falling into the flasks, and short tubes of quarter-inch pipe soldered on to them to connect with the flasks.

Although the heat of the sand was deemed amply sufficient to thoroughly sterilize the inner walls of the lead pipes, yet to leave no room whatsoever for doubt in regard to the sterility of the filters, the coils before being attached to the flasks were heated for some six hours at a temperature of over 250° in an air bath[*] constructed for this purpose.

After attaching the coils to the flasks the infusions were, as usual, boiled for over an hour. In experiment No. 56 the apparatus was allowed to stand for a week; in experiment No. 57 for nearly a month, before the filtrations were started. The percolation of No. 56 was effected in one day, while that of the longer tube required fifteen days; the filter was not, however, constantly supplied with water during the nights, and no attempts were made to hasten the filtration. The amounts of water added each day are recorded in the table. The pipe was coiled in several concentric helices, and the water in traversing its entire length was forced to pass alternately up and down the successive coils. The most favorable conditions were thus afforded for the filtration of the water in case the sand exerted any power whatsoever of removing the germs.

These tests show conclusively the utter worthlessness of sand as a filter for germinal matter.

The investigation into the absorption of inorganic salts and of nitrogenous organic matter by sand filters, which we hope at an early date to take up, derives an additional interest from these results. In view of the fact that sands fail to retain in their pores these particulate forms of matter it would appear highly improbable that they can exert, at least to any marked degree, an absorptive action on the still finer matters, organic or inorganic, of a solution. Should this prove to be the case, and should it furthermore be found, as the researches of Boussingaultt[†] would appear to indicate, that organic matter is oxidized with extreme slowness in a bed of sand, it will be seen that no reliance whatsoever can be placed upon it as a natural filter.

The facts here brought out seem to us of importance considered with reference to the sources of supply of our drinking waters; the relative locations of wells, cess-pools, &c., in our towns; and also with reference to the methods of removal of excreta, &c., especially during the prevalence of an infectious disease, the infective materials of which may be communicated through water. A good bed of sand has commonly been regarded as one of the most efficacious forms of filters, amply protecting our well-waters against all contaminations, even though the wells be sunk at no remote distance from sewers, cess-pools, cemeteries, &c. But we see that sand utterly fails to remove germs of putrefaction, &c., such as are normally found in the air and in water, from liquids; while its power of absorbing dissolved matter, organic or inorganic, must also be seriously questioned.

Nor do the sandy or even clayey soils afford us a safeguard against germ contamination of our well-waters, as the experiments with loess, clay, and clay mixtures would probably justify us in concluding, although it must be admitted that we have not here strictly the same physical conditions as in a natural soil which has not been subjected to heat.

The subject of germ transmissions through soils demands on the part of sanitarians the most searching investigation, not only on account of the possibility of contamination of our drinking waters through infiltration of germs, but also because the air, especially in our dwellings, may become infected if the soils in their natural conditions possess no power of retaining germs or their adult organisms. For whenever in an infected soil the ground water, from any cause, rises to the surface, germs may be carried with it and upon drying be taken up by the atmosphere.

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[*] It consisted of a galvanized-iron cylinder some 3 feet in length by 18 inches in diameter, with cross-bar supports, for the coil to rest upon, about a foot from the bottom; with slides to regulate the temperature, and apertures at the top and just below the coil-supports for thermometers.

[†] Boussingault: Comptes rend. '76; Jahresber. f. Ag. Ch. 1875-'76; XVIII-XIX, 42.

## LIQUID-FILTRATIONS—Continued.

TABLE III.—*Filtrations of water into sterilised infusions.*

| No. | Infusion. | Dimensions of tubes, &c., employed. | Filters. | | Date of experiment. | Subsequent treatment. | No. | Date of decomposition. | Time in— | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Kind. | Length in centimeters. | | | | | Days. | Hours. |
| 1a, c | Beef | Tube, 46 by $2^{cm}$ | Sand, 25° to 30°. Asbestus plug in neck of the tube. | 8 | Filled June 9 | A few drops of water filtered through July 9. | 1a, c | July 11 | 2 | .......... |
| 2b | Beef | Tube, $150^{cm}$ by $1.25^{cm}$, and flask, 1 liter. | Sand, 100° | 125 | July 24 | Filtration of water on the 26th instant. | 2b | July 28 | 2 | .......... |
| 3c | Beef | Flask, $250^{cm^3}$ | Sand, 30° to 50° | 5 | July 27 | Water added in just sufficient quantity to saturate the sand but not to filter through, August 3 and again August 18. | 3c | Aug. 16 | 13? | .......... |
| 4 | Beef (See note c.) | Tubes, 46 by $2^{cm}$ | Sand, 30° to 50° | 15 | July 13 | Water added to Nos. 4 to 7 on August 13, 14, 15, and 16. A few drops filtered through No. 4 on the 16th instant, through Nos. 5 to 7 on the 19th instant. | 4c | Aug. 17 | Less than 15 hours. | |
| 5 | | | | | | | 5c | Aug. 19 | Within 2 or 3 hours. | |
| 6 | | | | | | | 6c | Aug. 19 | Within 10 hours. | |
| 7 | | | | | | | 7c | Aug. 19 | | |
| 8 | Beef (See note d.) | Tubes, 46 by $2^{cm}$ | Asbestus (tightly packed). | 15 | July 23 | Filtrations of water into the infusions on August 24, 26, 28, 30, 31, September 1 and 2. | 8d | Sept. 7d | 14 | .......... |
| 9 | | | | | | | 9d | | | |
| 10 | Cucumber (See note d.) | | | | | | 10d | | | |
| 11 | | | | | | | 11d | | | |
| 12 | Beet (See note d.) | | | | | | 12d | Unk'n d | Unknown. | |
| 13 | | | | | | | 13d | | | |
| 14 | Beef (See note e.) | Tubes, 46 by $2^{cm}$ | Charcoal, 100° | 15 | Aug. 3 | Additions of water October 15, 16, 17, and 18. A few drops of water percolated No. 15 on the 18th, and No. 14 on the 19th instant. | 14e | Oct. 26 | 7 | .......... |
| 15 | | | | 7 | | | 15e | Oct. 22 | 4 | .......... |
| 16 | Beef (See note c.) | Tubes, 46 by $2^{cm}$ | Animal charcoal, coarse and fine, mostly 15°. | 15 | Aug. 28 | Additions of water on October 15 and 16. A few drops filtered through on the 16th instant. | 16c | Oct. 18 | 1 | 12 |
| 17 | | | | | | | 17c | | | |
| 18 | | | | | | | 18c | | | |

## SECOND SERIES OF EXPERIMENTS—Continued.

### LIQUID-FILTRATIONS—Continued.

TABLE III.—*Filtrations of water into sterilized infusions*—Continued.

| No. | Infusion. | Dimensions of tubes, &c., employed. | Filters. | | Date of experiment. | Subsequent treatment. | No. | Date of decomposition. | Time in— | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Kind. | Length in centimeters. | | | | | Days. | Hours. |
| 19 | Beef (See note *f*.) | Tubes, 46 by 2cm | **Animal charcoal, 100°** | 15 | Oct. 19 | Filtrations of water into Nos. 20 to 22 November 24, and into No. 19 November 27. Filtrations continued rapidly into Nos. 19 and 21 December 1, and into Nos. 19, 21, and 22 December 2, 3, 10, and 13, when the tubes were completely filled. Filtrations into No. 20 continued December 13, and carried on slowly. | 19*f* | Dec. 14 | 17 | .......... |
| 20 | | | | | | | 20*f* | .......... | **Still fresh.** | |
| 21 | | | | | | | 21*f* | Dec. 15 | 21 | .......... |
| 22 | | | | | | | 22*f* | Dec. 14 | 20 | .......... |
| 23 | Beef (See note *g*.) | Tubes, 46 by 2cm | **Charcoal, 25° to 50°** | 15 | Oct. 19 | Filtrations of water Nov. 23 | 23*g* | Nov. 28 | 4 | 12 |
| 24 | | | | | | | 24*g* | | | |
| 25 | | | | | | | 25*g* | | | |
| 26 | Beef (See note *h*.) | Tubes, 46 by 2cm | **Mixture of sand,* 18° to 100°, 3 parts, and pure kaolin 1 part, by weight.** | 15 | Sept. 24 | Additions of water to 26 to 28 on October 15 and 16. A few drops filtered through on the 16th instant. Filtrations of 26 and 27 continued on the 19th instant, as the infusions were still clear. | 26*h* | Oct. 22 | 6 | .......... |
| 27 | | | | | | | 27*h* | Oct. 20 | 4 | .......... |
| 28 | | | | | | | 28*h* | Oct. 19 | 3 | .......... |
| 29 | | | | | | Filtrations of 29 to 31 begun October 18 and continued until the 22d instant, when a small quantity was filtered turough. Further filtration of 29 on the morning of the 25th instant, as the infusion remained clear. | 29*h* | Oct. 25 | 3 | .......... |
| 30 | | | | | | | 30*h* | Oct. 23 | 1 | 3 |
| 31 | | | | | | | 31*h* | Oct. 23 | 1 | 12 |
| 32*i* | Beef (See note *h*.) | Tubes, 46 by 2cm | **Mixture of sand, 18° to 100°, 1 part; kaolin, 1 part.** | 15 | Nov. 3 | Filtration of water into Nos. 33 and 35 November 23, and into Nos. 32, 34, 36, and 37 November 24. The filter columns were kept saturated, and the filtrations proceeded very slowly from day to day. | 32*i*, *h* | Dec. 14 | 20 | .......... |
| 33 | | | | | | | 33*h* | Dec. 1 | 8 | .......... |
| 34 | | | | | | | 34*h* | Dec. 2 | 8 | .......... |
| 35 | | | | | | | 35*h* | Nov. 27 | 4 | .......... |
| 36 | | | | | | | 36*h* | | 3 | .......... |
| 37 | | | | | | | 37*h* | | | |

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|---|---|---|---|---|---|---|---|---|---|---|
| 38 | Beef (See note *h*.) | Tubes, 46 by 2$^{cm}$ | Kaolin | 15 | Nov. 3 | Filtrations of water into Nos. 38 to 41 and 43 November 24, and into No. 42 November 27. Filtrations continued very slowly from day to day. | 38*h* | Nov. 29 | 5 | |
| 39 | | | | | | | 39*h* | Nov. 30 | 6 | |
| 40*i* | | | | | | | 40*i*, *h* | Dec. 13 | 19 | |
| 41 | | | | | | | 41*h* | Nov. 28 | 4 | |
| 42 | | | | | | | 42*h* | Nov. 30 | 3 | |
| 43 | | | | | | | 42*h* | Nov. 28 | 4 | |
| 44 | Beef (See note *j*.) | Tubes, 46 by 2$^{cm}$ | Coal-ashes, 10° to 100° | 15 | Nov. 3 | Filtrations of water begun November 23 and continued from day to day until decomposition ensued. Filtrations carried on rapidly December 2 and 3, the tubes being nearly filled. No. 49 was completely filled December 10. | 44*j* | Dec. 4 | 11 | |
| 45 | | | | | | | 45*j* | Dec. 4 | 11 | |
| 46 | | | | | | | 46*j* | Dec. 7 | 14 | |
| 47 | | | | | | | 47*j* | Dec. 8 | 10 | |
| 48 | | | | | | | 48*j* | Dec. 9 | 16 | |
| 49 | | | | | | | 49*j* | Dec. 12 | 19 | |
| 50 | Beef (See note *h*.) | Tubes, 46 by 2$^{cm}$ | Loess, 100° | 15 | Nov. 4 | Filtrations of water begun November 23 and continued slowly from day to day until the infusions decomposed. | 50*h* | Nov. 30 | 7 | |
| 51 | | | | | | | 51*h* | Nov. 29 | 6 | |
| 52 | | | | | | | 52*h* | Dec. 1 | 8 | |
| 53 | | | | | | | 53*h* | Nov. 29 | 6 | |
| 54 | | | | | | | 54*h* | | | |
| 55 | | | | | | | 55*h* | | | |
| 56*k* | Beef | Lead pipe, 23 feet by 1 inch, and flask, 1 liter. (See figure 4.) | Sand, 18° to 100° | 22 feet | Sept. 6 | Filtration September 13, 1,500$^{cm3}$ of water being added. | 56*k* | Sept. 15 | 2 | |
| 57*k* | Beef | Lead pipe, 101 feet by 1 inch, and flask, 1 liter. (See figure 4.) | Sand, 18° to 100° | 100 feet | Sept. 24 | Additions of water (well water containing fungoid growths, &c.):<br>1,000$^{cm3}$, October 18.<br>700$^{cm3}$, October 19.<br>300$^{cm3}$, October 20.<br>400$^{cm3}$, October 21.<br>400$^{cm3}$, October 22.<br>400$^{cm3}$, October 23.<br>300$^{cm3}$, October 24.<br>300$^{cm3}$, October 25.<br>260$^{cm3}$, October 26.<br>260$^{cm3}$, October 27.<br>260$^{cm3}$, October 28.<br>260$^{cm3}$, October 29.<br>260$^{cm3}$, October 30.<br>260$^{cm3}$, October 31.<br>240$^{cm3}$, November 1.<br>5,600$^{cm3}$<br>Some 100$^{cm3}$ filtered into the infusion by midnight of November 1. | 57*k* | Nov. 3 | Nearly 2 | |

## NOTES TO TABLE III.

*a* See No. 14, First Series, Table I.

*b* In No. 2 the open tube was fitted air-tight into the flask by means of a rubber stopper. T
was provided with a second tube plugged with asbestus for steam-escape during ebulliti
escape during filtration. The bacterial developments were very rapid and profuse.

*c* Bacterial growths very abundant.

*d* Tubes 8 to 13 were filled with water September 2. September 7 Nos. 8, 9, 10, and 11 s
*faint* traces of bacterial growths. These growths have increased but very little since the
tember. The dates for Nos. 12 and 13 could not be determined, so faint were the signs of gr
tubes were apparently perfectly clear for a month, and on December 18 No. 13 still showed
*slight* opalescence. Microscopical examination of No. 13 December 18 revealed but the mere
bacterial growths. Microscopical examinations of Nos. 8 and 9 December 23 revealed very
terial growths (*B. termo*, &c.).

*e* Bacterial growths distinct in No. 14 and abundant in No. 15. (Ordinary bacteria of put
*termo*, and also *B. lineola*.)

*f* The filtrations were carried on very rapidly in Nos. 19, 21, and 22; bacterial developmen
very slow. Examined under the microscope December 23. Bacterial growths in Nos. 21 and
but not abundant. Microscopical examination January 26 (*B. termo; Micrococci; Bacill*
*ulna?; Spirilla—Spirillum-undula*).

*g* Bacterial growths very rapid.

*h* Decomposition rapid. Microscopical examinations of several of these infusions showed
*B. termo* and *Bacillæ*.

*i* A few drops of water filtered through on November 24. Subsequently, scarcely an
amount passed the filters.

*j* Bacterial growths slow, but finally profuse.

*k* In No. 56 the lead pipe was connected with the flask by a lead tube 6 by ½ inches, which w
to the pipe and passed air-tight through the rubber stopper of the flask. In No. 57 the lead
enter the flask directly, but was connected with a glass tube of same diameter, which pas
the rubber stopper, by rubber tubing to which a pinch-cock was attached to control the fl
into the infusion. The bacterial growths were very rapid and abundant in both flasks.

### THIRD SERIES OF EXPERIMENTS—TRANSMISSION OF GERMS FROM A LIQUID TO THE AIR.

The question whether germs could be taken up by the atmosphere from a wet soil or a putrescent liquid was one which early engaged our attention. It has of late years been affirmed by many writers that germs are freely given off to the surrounding air through the evaporation of a liquid. The researches of Nægeli,[*] and the still more recent investigations of Carmichæl,[†] Wernich,[‡] Miquel,[§] and others, published during the present year in various scientific journals, have, however, conclusively proved the falsity of this view, their experiments clearly showing that, under normal conditions of temperature at least, germs are never given off from a liquid at rest or from a thoroughly moistened sand or solid matter of any kind. Although we became acquainted with the results of these researches during the progress of our own investigation, nevertheless it seemed desirable to continue the experiments in view of the many important sanitary interests involved.

In our study of the deportment of liquids, with reference to their germinal matters, three questions were considered, viz:

1. *Can a liquid give off germs to the superincumbent atmosphere when both are in a state of rest?*
2. *Can a current of air take up germs from a liquid at rest?*
3. *Can a liquid part with germs when bubbling, in consequence of the evolution of gases produced by its own fermentation, &c., or of the aspiration of air through its mass?*

To test the first question (experiments 1 to 6) the form of apparatus shown in Fig. 5 was employed. It consists essentially of a wide-necked flask, for the sterilized infusion (*d*), into which a moderately wide tube, bent near the lower extremity so as to form a trap for the sewage, putrid infusion, &c. (*f*), is inserted. The longer arm of this tube passes air-tight through a rubber stopper in the neck of the flask and communicates freely with the outer air. The stopper contains in addition an asbestus filter-tube (*e*).

The infusions were boiled as usual for a long time to insure the sterility of the flasks and entire contents, the rubber stoppers being lightly inserted and the bends of the trap-tubes being filled with a little distilled water. While the flasks were cooling, these tubes were tightly stoppered to prevent the entrance of unfiltered air. The tube-stoppers were then removed and the decomposing liquids cautiously added, by means of a pipette, until they filled the tubes to within about half an inch from the tops of the shorter arms. The apparatuses were then allowed to stand at rest.

In the experiments (Nos. 7–9) on the second question U-tubes were employed as traps, which were connected with the flasks by narrow tubing, as seen in Fig. 6. Both the flasks and the traps contained asbestus tubes. In preparing the experiments the flasks and U-tubes detached were boiled for a long time, the bends of the latter being filled with distilled water. They were then connected by rubber tubing and the boiling continued for some time, the connecting-tube (*c*) being raised a little above the surface of the infusion in the flask. The portions of the connecting tubes above the flasks were at the same time strongly heated in order to absolutely insure the destruction of all germs in them, and the asbestus tubes were likewise warmed to prevent the condensation of steam. The open arms of the U-tubes were, as before, stoppered while the apparatuses were cooling, in order that only filtered air might enter the flasks. The U-tubes were then nearly filled with the decomposing liquids, the small quantity of distilled water in the bends of the tubes serving to prevent the entrance of air during the operations, and the connecting tubes (*c*) gently forced down into the infusions. The asbestus tubes (*a*) of the flasks were then connected with aspirators, and the air was drawn at any desired rapidity through the asbestus tubes (*b*), which filtered it, over the surface of the putrescent liquids (*f*) and through the infusions (*d*). By this means, it will be seen, only germs given off from the liquids of the traps could enter the infusions.

To test the third question (experiments 10–13) the form of apparatus just described was at first employed, with the single modification that the asbestus tube (*b*) was drawn out to a capillary tube, which terminated below the surface of the putrescent liquid.

Some difficulty was, however, experienced with this form of the apparatus, as the liquids were gradually forced up the closed arm of the U-tube, a considerable pressure being required to maintain the aspiration through the fine capillary tubes. The experiments required, consequently, very careful watching, and the aspirations could not be carried on constantly and at a very slow, uniform rate. To obviate this difficulty, a straight closed tube was finally employed (experiment 11), as shown in Fig. 7.

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[*] Nægeli: Die niederen Pilze, u. s. w., München, 1877.

[†] Carmichæl: An experimental investigation into the trap and water-closet system, &c. The San. Jour., vol. iv, No. 49, March 1, 1880, Glasgow.

[‡] Wernich: Ueber verdorbene Luft in Krankenräumen, No. 179, Sammlung Klin. Vorträge, Februar, 1880, Volkmann.

[§] Miquel: Epuration des eaux d'égouts par le sol de Gennevilliers, Journal D'Hygiène, &c., 1880, $5^e$ vol., 333 p. Report by Marié-Davy.

In preparing the experiment this tube was first sterilized by heat; the sewage was then added through a funnel, so as not to wet the upper part of the tube, and the tube connected with the flask while the infusion was still boiling, the stopper, however, only being loosely inserted so long as the boiling was continued. The customary precautions were taken to insure the sterility of the connection-tube (*c*) and the portion of the tube above the surface of the sewage (*f*). With this form of apparatus the aspiration was constantly maintained.

The results of the experiments confirm the observations recorded by the other experimenters referred to.

*At normal summer temperatures no germs were given off from the decomposing liquids whenever their surfaces remained unbroken, even though in some of the experiments the air was continuously conducted over them in a slow current. When the surfaces of the liquids were broken, however, by the bursting of bubbles, germs were invariably given off and the sterilized infusions infected, no matter how slowly the aspiration was conducted.*

In most cases (experiments Nos. 10, 12, and 13) the infection of the infusions resulted very speedily; in a single instance (No. 11), where the aspiration was conducted with extreme slowness, it was somewhat retarded, though not ultimately prevented.

In these experiments two possible sources of error occurred to us. The traps and the connecting tubes were speedily coated with moisture from the condensed vapors of the infusions and the trap-liquids. There might thus, it is obvious, be a direct continuity of the liquids in the traps and the cultivating-flasks by means of these thin films of moisture in all the experiments of the second and third sets, as well as in some of those of the first set, for in some instances here the traps were in direct contact with the surface of the cultivating-liquid, and not raised slightly above it, as represented in the figure.

Might not germs then from the trap-contents be conveyed along these moistened surfaces into the sterilized infusion by capillary action, or might these condensed vapors not contain a sufficient amount of germ nutriment to enable fungi to spread from the traps to the infusions?

Although the possibility of direct infection of the infusions in either way seemed extremely slight, yet as the remotest source of error in experiments of this nature should be rigidly guarded against, in some of the tests (Nos. 12 and 13) the bends of the connection-tubes (*c*) were kept perfectly free from moisture during the entire time of experimentation, by means of a gentle heat. This source of error was in these cases, therefore, entirely eliminated. The infusions, however, decomposed as in the other experiments where the aspiration was through the trap-liquids. The results of the other experiments show, furthermore, that inoculation does not take place from such causes.

On the other hand, might not the presence of moisture in the connecting-tubes (*c*) of the second and third sets of experiments have precisely the opposite effect, *i. e.*, to prevent, or at least to retard, the transference of germs from the traps to the cultivation-fluids, in case any were taken up by the air?

This objection, though likewise of no great weight, was the more plausible of the two, as the germs in passing through the long, narrow connection-tube (*c*) might all at some point come in contact with its moistened walls and adhere to them.

To meet the objection control-tests (experiments 14 to 17) were tried. In experiment No. 16 the asbestus was removed from the filter-tube (*b*), so that air which contained germs might be aspirated. In experiments Nos. 14 and 15 no traps were employed; the tubes (*c*) opening downwards, as before, were lengthened to $25^{cm}$ to increase the possibility of contact; and the aspirations were carried on more slowly than in the tests of the second set. In No. 14 the tube was kept constantly moist, but in No. 15, in which it was drawn out to a long capillary tube, it was allowed to dry. In experiment No. 17 the asbestus was removed from the filter-tube (*b*), which was drawn out to a capillary tube as in experiments 10 to 13, and the aspiration was conducted through sterilized water.

In all of these control-experiments the infusions ultimately broke down. Neither by conducting unfiltered air through sterilized water nor over moistened surfaces can the germs be removed therefrom; though, as a comparison of the tabular results of all the experiments would appear to indicate, the passage of germs is to a certain extent retarded.

We have just stated as one of the results of these experiments that germs are not given off from an infusion at rest to the air at the ordinary summer temperatures. It will be seen, however, from the table that in four experiments of the first set the infusions finally decomposed. Setting aside the result of experiment No. 2 as untrustworthy, the flask having evidently been disturbed,* we have in experiments 1, 4, and

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* One side of the shorter arm of the trap was, on the date of the decomposition, found to be coated with decomposition products of the putrid infusion up to the edges of the tube.

5 cases of decomposition occurring at the expiration of ninety-two, eighty-three, and one hundred and seventeen days, respectively, for which we can at present offer no satisfactory explanation.

The flasks in this set of experiments were by chance all placed on a shelf in the laboratory directly over a furnace register. The temperature of the air immediately surrounding the flasks was thus considerably higher than the average temperature of the room, after the furnace fires were started—about the middle of October. No absolute record of the extreme daily limits of temperature was made until November 18, when, in consequence of the decomposition of No. 1, maximum and minimum thermometers were placed by the flasks. The temperature was frequently observed, however, and found on several occasions to run as high as 35°, and on October 25 to have reached 37°.

The very surprising cases of decomposition at these temperatures suggest the interesting question whether germs may not be taken up by the air at temperatures within the limits of our extreme summer heats, though they are not given off at temperatures but slightly below these.

With reference to the effect of temperature upon the transmissions of germs from a liquid to the air, our attention has recently been called by Dr. Bigelow to the statement by Miquel,[*] that in the evaporation of putrid liquids at temperatures of 40–45°, though not at lower temperatures, the aqueous vapors carry germs with them into the air. On the other hand, Marie-Davy, in the article previously referred to, reports that Miquel in some recent investigations evaporated putrid infusions to dryness at temperatures of 40° and 45° without observing any transmissions of germs.

In our own experiments the temperature has, since November 18, repeatedly reached 39° and occasionally 42° without any further decompositions occurring. It must, however, be remembered that these temperatures have not been maintained for any great length of time.

That germs can be given off from a quiescent liquid to the air, even at high temperatures, has not been directly proven, and we should by no means feel warranted in assuming this as the cause of the decompositions above cited, although we are not at present able to account for them in any other way.

As the tubes were constantly covered with films of moisture from condensed vapors there was no possibility of the bacterial growths drying around the surface-edges of the infusions in the inner arms, nor, were that to happen, would it seem probable, judging from Wernich's[†] experiments, that germs could become detached and taken up by the air in the flasks.

The other experiments of this series show that germs can neither be carried up the tubes by capillary action nor reach the cultivating-liquids by direct, continuous lines of growth.

The flasks were naturally subject to fluctuations of temperature on account of their location. On the supposition that the traps might at times, under sudden fluctuations of temperature, have been forced, in consequence of the asbestus filter-tubes resisting to a slight degree a rapid egress or ingress of air, control-experiments were at one time made with several of the flasks which had decomposed, by placing them directly over the register, where the temperature was 70–75°, and then removing them quickly to the outer air, the temperature of which was about 0°. At the instants of exposure to the hot and cold air slight displacements of the liquids in the tubes were perceptible; which were, however, only momentary, the air passing freely through the asbestus. On another occasion the flasks were subjected to temperatures of 107° and —7°. Although these changes of temperature were much greater and more sudden than any to which the flasks could have been previously exposed, yet we did not succeed in any instance in forcing the trap-contents over into the infusions.

The fact that the infusions remained perfectly clear for several months, and then suddenly and rapidly decomposed, precludes the possibility of their having been incompletely sterilized.

The results of investigations thus far indicate, however, that in experiments on this problem the temperature must be taken into consideration as one of the factors. In consequence of these results we purpose to continue this entire series of experiments on the transmissions of germs from quiescent liquids, in cultivating-chambers at constant temperatures from 35° to 45°, or even higher if necessary.

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[*] Miquel: Annuaire Météorologique de Montsouris, 1878, 540 p.

[†] *Loc. cit.*

## THIRD SERIES OF EXPERIMENTS.

*Transmission of germs from a liquid to the air.*

| No. | Infusion. | Dimensions and forms of apparatus. | Date of experiment. | Dates of aspirations. | No. | Date of decomposition. | Time in— |  | No. of liters of air aspirated before decomposition. |
|---|---|---|---|---|---|---|---|---|---|
|  |  |  |  |  |  |  | Days. | Hours. |  |
| 1*a*<br>2*b*<br>3 | Beef ....... | Liter flasks with bent tubes ($1^{\text{cm}}$ in diameter) as traps, containing water (No. 1); beef infusion (No. 2); urine (No. 3). (See figure 5.) | Aug. 5 | ........................................ | 1*a*<br>2*b*<br>3 | Nov. 5<br>Aug. 25<br>........ | 92<br>20*b*<br>........ | ........<br>........<br>........ |  |
| 4*a*, *c*<br>5*a*, *c*, *d*<br>6 | Beef ....... | Same as above; Nos. 4 and 5 containing beef infusion, No. 6, sewage in the traps. | Aug. 27 | ........................................ | 4*a*, *c*<br>5*a*, *c*, *d*<br>6 | Nov. 18<br>Dec. 22<br>........ | 83<br>117<br>........ | ........<br>........<br>........ |  |
| 7<br>8<br>9 | Beef .......<br>(See note *e*. | Flasks ($500^{\text{cm}^3}$) with U-tubes ($10\times2^{\text{cm}}$) as traps, containing beef infusion (No. 7); urine (No. 8); sewage (No. 9). (See figure 6.) | Aug. 12<br>Aug. 12<br>Aug. 21 | Nos. 7 and 8 daily and continuously from August 13 to August 21, inclusive; and Nos. 7, 8, and 9 continuously from August 24 until September 17, inclusive (excepting August 30); and on September 21, 22, 24, and 25, averaging about 3½ liters a day. | 7<br>8<br>9 | ........<br>........<br>........ | ........<br>........<br>........ | ........<br>........<br>........ | Up to date.... 126<br>Up to date.... 126<br>Up to date.... 102 |
| 10 | Beef .......<br>(See note *f*. | Nos. 10, 12, 13, flasks (1 L.) with U-tubes ($10\times2^{\text{cm}}$), containing sewage (Nos. 10 and 12), and beef infusion (No. 13). | Aug. 21 | No. 10 at intervals from August 24 until August 28, inclusive. | 10 | Aug. 29 | ........ | ........ | A little more than 2 |
| 11 |  | No. 11, flask (1 L.) with straight tube ($10\times2.5^{\text{cm}}$), containing sewage. (See figure 7.) | Sept. 7 | No. 11 continuously and *very slowly* from September 14 to September 25, inclusive; and from October 18 to November 9, inclusive, averaging $333^{\text{cm}^3}$ (September 14 to 25) and about $870^{\text{cm}^3}$ (October 18 to November 9) per day. | 11 | Nov. 10 | ........ | ........ | From Sept. 14 to Sept. 25 ....... 4<br>From Oct. 18 to Nov. 9 .........20<br>In all.............24 |
| 12 |  | ........................................ | Sept. 1 | No. 12 at intervals from September 2 to September 3, inclusive. | 12 | Sept. 4 | ........ | ........ | Less than ....... 2 |
| 13 |  | ........................................ | Sept. 6 | No. 13 at intervals from September 13 to September 15, inclusive. | 13 | Sept. 16 | ........ | ........ | $300^{\text{cm}^3}$ |
| 14 |  | Nos. 14 and 15, flasks (1 L.) without traps, and with tubes *c* $25^{\text{cm}}$ in length. In No. 15 tube *c* was drawn out to a capillary tube for $10^{\text{cm}}$ of its length. | Sept. 1 | No. 14 continuously from September 2 until September 14, inclusive, averaging $1.846^{\text{cm}^3}$ per day. | 14 | Sept. 15 | ........ | ........ | 24 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | September 4, inclusive, averaging $1.600^{\mathrm{cm}^3}$ per day. | | | | | |
| 16[e] | Beef ...... (See note g. | Flask (1 L.) with U-tube, as No. 7, containing water, but with no asbestus in tube *b*. | Sept. 2 | No. 16 continuously from September 3 until September 12, inclusive, averaging $1.800^{\mathrm{cm}^3}$ per day. | 16 | Sept. 13 | ........ | ........ | 18 |
| 17[f] | | Flask (½ L.) with U-tube, as Nos. 10–13, containing sterilized water. | Sept. 2 | No. 17 at intervals from September 3 until September 24, inclusive. | 17 | Between Sept. 25 and Oct. 13. | ........ | ........ | 24 |

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[a] Until October 25 the temperature ranged from about 20° to 35°. Temperature October 25, 37°. From October 25 until November 5 ranged from 30° to 35°; exact limits not known.

[b] Flask appeared to have been disturbed.

[c] The extreme limits of temperature from October 25 until November 18 not known with precision; highest observed temperature, 36°.

[d] Between November 18 and December 22 the temperature (as indicated by a maximum thermometer) ran: on 12 days above 37°; on 9 days above 38°; on 6 days above 39°; on 5 days to 40°; on 3 days to nearly 43°.

[e] In Nos. 7 and 8 tube *b* terminated just above the surface of the liquid in the trap; tube *c* near upper extremity of the trap. In No. 9 position of tubes reversed, tube *c* terminating directly above the surface of the trap-contents, &c. The temperature ranged from about 20° to 35°—highest observed temperature.

[f] Tubes *b* terminated in capillary tubes below the surface of the liquid to produce bubbling. Tubes *c* terminated near the surface of the liquids. In Nos. 10 and 11 the bends of tubes *c* were moist; in Nos. 12 and 13 they were kept dry and warm.

[g] Tube *c* was kept moist in No. 14 by addition of a drop of water from time to time, but allowed to dry in No. 15. In No. 16 it remained moist, the aspiration being over water. In No. 17 the aspiration was through the boiled water, to see how long it would filter out the germs.

In addition to the foregoing investigations, a few experiments have been tried by us to test the effects of carbonic acid under pressure on bacterial growths. To this end, small quantities of beef infusions were put into siphons and the bottles charged as usual, under a pressure of about 150 pounds. Carbonic acid under this pressure did not in any case prevent the development of organisms, though it apparently retarded it.

We have also begun a series of experiments to determine the rapidity of the spread of bacterial growths along tubes or through columns of sand and other soils moistened with nourishing liquids, the results of which, however, we are not at present able to communicate.

Tests of the permeability and the filtering power of cemented walls are being tried.

Since the date of the foregoing report the work has been steadily prosecuted in a continuation and extension of the experiments designed to test the capacities of soils as filters in eliminating the living low forms of vegetable life, both germs and adult organisms, from ground water and ground air. In the progress of the experiments, which will be fully detailed in a future report, it has been ascertained:

1. That spongy iron surpasses all other bodies yet tried as a protective filter for water. Under slow filtrations it is found to eliminate germs completely from even foul waters, being superior in this respect to animal charcoal. It does not, however, withstand rapid filtrations, and the general result of the investigations would seem to lead to the conclusion that no material yet suggested can remove the germs from rapidly flowing water.

2. The slow and rapid quantitative air filtrations through sands and gravels have been largely extended with interesting results, which show that dry soils exhibit even in comparatively coarse grains a marked filtering capacity for germ-laden air. They show further that wet filters are still more efficacious than those that are dry, and that putrid soils not only retain the germs which they already possess, but also extract others from air passing through them.

3. Other experiments make it almost positively certain that germs are not given off by a quiescent liquid or by moist soil, even when a slow current of perfectly dry air is passing over them, at any temperature in which germ life can flourish. It is not probable, therefore, that specific disease *germs* can be given off from the trap water of closets, whatever may be the case with sewer gases without germs.

4. Experiments have been commenced with a view to determine the depth to which germs penetrate below the surface and to test the filtering power of cements.

5. The discovery that soils possess no power to remove germs from flowing liquids, while they are easily detached from dry materials and taken up into the air, has suggested the importance of testing the filtering powers of all materials entering into the structure of houses, especially such as are used for foundation walls, &c.

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# APPENDIX 6.

## *QUARANTINE AT NEWPORT, R. I.*

OCTOBER 10, 1881.

Hon. A. H. LITTLEFIELD,
*Governor of Rhode Island, Providence, R. I.:*

SIR: I have the honor respectfully to call your attention to the inclosed copies of (1) an official communication to the president of the National Board of Health by Samuel Powel, esq., president of the Sanitary Protective Association of Newport, and (2) of a letter addressed by the former to his honor the mayor of that city.

This correspondence having been submitted to the executive committee, and no reply having been received from the mayor of Newport, I have been directed to lay the whole matter before your excellency.

In the execution of this duty I beg leave to invite your attention to a paper on the history of quarantine legislation in Rhode Island, by Dr. David King, of Newport, as contained in the National Board of Health Bulletin for September 10, 1881, a copy of which will accompany this communication. From the statements in this paper it appears that vessels infected with yellow fever or other infectious disease were required, under a heavy penalty, to anchor one mile distant from a landing place. And yet, with a singular inconsistency, the city ordinance now in force prescribes that "the quarantine ground of the city of Newport shall comprise all that part of the harbor extending north from a line drawn from the light-house on Goat Island to the south extremity of Fort Green, and east of a line drawn from the head of Long Wharf to the western extremity of Coaster's Harbor Island. The mayor, or, in his absence, a member of the board of aldermen, shall determine at what distance from the asylum on Coaster's Harbor Island the quarantine vessels shall be placed, so that the health of the poor that may be in the asylum may not be endangered." (Laws of the State of Rhode Island relating to the city of Newport, and ordinances of the city, 1879, p. 155, chap. 21, sec. 2.)

You will not fail to observe that while a proper regard was had for the safety of the inmates of the asylum, no thought was given to the security of a large part of the city now closely built up almost to the water's edge along the defined limits of the quarantine anchorage. The matter is further complicated by the fact stated in Mr. Powel's communication, that the greater part of this very area has been recently ceded to the United States for a training school for the Navy.

I am, very respectfully, your obedient servant,

J. L. CABELL,
*President of the National Board of Health.*

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SEPTEMBER 8, 1881.

To Dr. J. L. CABELL,
*President National Board of Health:*

DEAR SIR: Acting upon the request of one of our leading members of the Newport Sanitary Association—chartered for our mutual sanitary protection, and for other purposes—I take the liberty, as one of the members of said association, to represent to you that I am credibly informed and verily believe that the city of Newport is at this moment without any practical quarantine ground, inasmuch as the land set apart for the same is the same land which has recently been turned over in part to the National Government for the Marine or Naval Training School plant; and, besides, that several members of our association reside upon land within a portion of the limits outside of the training school land, at Courter's Harbor. My especial impulse for thus writing to you is—besides the knowledge that yellow fever now exists in the West Indies, and at Key West, an important port in the State of Florida—and that, besides, a vessel yesterday entered our harbor with flag at half-mast, having a man dead on board from Southern malignant fever, as decided by the physician who visited the vessel, and, as you well know, it is very possible to make error in such diagnosis in many cases where the history may be unknown and no autopsy being made.

I am impressed with the importance of having a regular competent physician appointed as soon as possible, whose responsible duty it shall be to act as an official quarantine physician, and that there shall be set apart as soon as possible a proper quarantine station for the safety of ourselves, and for the proper convenience and comfort of those entering our port in distress. It is proper to say that I am entirely ignorant who was the physician who boarded the vessel in question, and that whoever he be I have not in this note the slightest disposition or willingness to make stricture upon the gentleman who was ready to risk his life in doing his duty for the safety of our homes.

Very respectfully, yours,

SAMUEL POWEL,
*President Sanitary Protective Association of Newport, R. I.*

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NEWPORT, R. I., *September* 9, 1881.

Hon. —— SLOCUM,
*Mayor of Newport:*

SIR: I have this morning received a communication, addressed to me in my official capacity as president of the National Board of Health, by Samuel Powel, esq., president of the Sanitary Protective Association of Newport, relative to certain alleged defects in the mode of executing quarantine regulations in this harbor. Inasmuch as the act of Congress, entitled "An act to prevent the introduction of contagious and infectious diseases into the United States," approved June 2, 1879, imposes upon the National Board of Health the duty, in a certain contingency, of taking cognizance of such defects in the quarantine regulations enforced by local authorities as may be likely to prove detrimental to the public health, by facilitating the introduction of contagious or infectious diseases, it will be my duty to refer the communication of Mr. Powel to the executive committee of the board, to which body I shall be glad to refer, also, any statement you may wish to make on the subject.

The specific allegations will be found in the inclosed copy of Mr. Powel's letter. I venture, in advance of any action which the executive committee may take with reference to this matter, to respectfully suggest that it would probably allay the fears of the community, and otherwise prove beneficial, if the quarantine anchorage were transferred to a locality more remote from the city, and a competent medical officer were appointed to inspect all vessels with sickness on board or sailing from Southern ports between the 1st of June and the 1st of November of each year.

Any communication you may desire to address to the National Board of Health may be sent to me at the residence of H. B. Auchincloss, esq., until Monday morning, or after that date to Dr. F. J. Turner, secretary of the board, Washington, D. C.

Very respectfully, yours,

J. L. CABELL.

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## ORIGIN AND GROWTH OF THE QUARANTINE SYSTEMS OF THE UNITED STATES, BY STEPHEN SMITH, A. M., M. D., OF NEW YORK.

### STATE OF RHODE ISLAND.

By David King, M. D., *of Newport, R. I.*

The first law passed by the general assembly of Her Majesties Colony of Rhode Island and Providence Plantations, in relation to quarantine, was during its session at Newport on the 27th day of February, 1711. It is entitled "An Act to Prevent the Spreading of Infectious Sickness," and reads as follows:

"Whereas *Contagious Distempers have been several times brought into this Colony, by the Masters of ships and other vessels, Coming into the several Ports of this Colony, from Places that are Infected therewith:*

"For the preventing whereof for the Future,

*Be it enacted by the General Assembly*, and by the authority of the same, That no master or commander of any ship or other vessel, that shall come into any port or Harbour of this Colony, and shall in their passage hereto, have any person or persons sick on shipboard with the small-pox, or any other Contagious Disease, or shall come from any port or place where any Contagious Distemper is brief or prevalent, shall not bring to anchor their ship or vessel, in any of the ports of this government, within the distance of one mile of any publick ferry, pier, or landing place; or if any vessel or vessels that are at anchor therein, shall land nor suffer any person or persons, on board such ship or vessel to be landed, nor suffer any persons to come on board such ship or vessel, without a license first had from the Governour of this Colony for the time being, if they shall anchor in the harbour of Newport, or in his absence from one or more justices of the peace of said town, and if they shall anchor in any other harbour of this Colony, a license shall be first had and obtained from some one or more justices of the peace of such town, under penalty of forfeiting one hundred pounds, good and lawful money of this Colony, to and for the use of the Colony, to be recovered by the General Treasurer of the Colony in the general Courts of Tryals of this Colony; by bill, plaint or information, and where the Offender or Offenders herein, shall have no essoin, protection or wager of law allowed.

"*And be it further enacted by the authority aforesaid*, That if upon the arrival of any such ship, or other vessel as aforesaid, in any harbour of this Colony, as aforesaid, any passenger on board, or any mariner thereto belonging, shall and do come on shore or land from such vessel, without a licence first had and obtained as aforesaid, that then, and in such cases, it shall and may be lawful for any justice of the peace of such town, where such person and persons shall land, to require and command, and send such person and persons so offending, on board such vessel again, or to confine them ashore to any such place, as to him shall seem Convenient, for to prevent the spreading of any infection; and the person or persons so offending, shall answer, satisfy and pay all charges that shall arise thereon, and shall forfeit twenty pounds, good and lawful money of said Colony, to and for the use of the Colony, to be recovered as aforesaid.

"And if the Offender or offenders have not estate sufficient to satisfy and pay the same, that they shall be set to work, by the direction, and at the discretion of the judges of such Court where such cause shall be tryed, until the same be fully satisfied and paid.

"And for the better putting this Act in Execution,

"*Be it enacted by the authority aforesaid*, That the Naval officer shall keep of this act publickly set up in his office, for the view of all masters of ships, and other vessels that shall enter with him; and the said Naval officer is hereby impowered upon any information unto him given of any ship or vessel arriving in this harbour, that any infectious distemper aboard, to send on board of such ship or vessel, a doctor to examine the same, as need shall require, and return thereof to the Governour, or in his absence, to some of the Assistants, or justices of the peace of the town of Newport to make report, that due care may be taken therein; and the master of such ship or vessel, shall pay all charges arising thereon; and if he refuse to pay the same, it shall be recovered by the Naval officer* in any Court of record within this Colony.

"*And be it further enacted by the authority aforesaid*, That if, notwithstanding the above said precautions to prevent any infectious distemper from being brought into this Colony, that if any person or persons, passengers, mariners, or slaves, shall be landed from on board any ship, or other vessel, and shall, after being landed, be taken sick with the small-pox, or any other infectious distemper; that then and in such case, it shall and may be lawful, for any one assistant or justice of the peace of any such town where such cause shall happen, to remove such sick and distempered person and persons to such convenient place as shall to them appear to be necessary, to prevent the spreading thereof; and the person or persons so removed, if free to pay the charge thereof, and shall be recovered in any court of record within this Colony, by the person or persons that shall disburse the same; and if the persons so removed be slaves, then the owners thereof shall pay the same; and if the slaves are consigned to any person within the government, then such persons to whom consigned, shall pay the charge of the same, to be recovered as aforesaid."

June, 1731. An act passed by the general assembly of Rhode Island, at Newport, June, 1731, to prevent vessels coming into the government from places infected with the small-pox.

"Every master of any ship or other vessel that shall come into the harbour of Newport and shall not bring to his vessel [at the Fort, Fort George]; When the Gunner shall fire a shot at him, shall for the first shot pay ten shillings, and for the second twenty shillings, and for every shot after the second Five Pounds; and the Naval Officer shall, before he clear said vessel, receive the same, and shall have three shillings as a fee for the same. All which fines to be for the use of the Colony."

February, 1743. An act passed by the general assembly of Rhode Island in February, 1743, to prevent the spreading of small-pox and other contagious sickness in this colony, with the following preamble:

"Whereas the Small-Pox and other Contagious Distempers have been several times brought into this Colony by masters of ships and other vessels coming from infected places, which has proved of pernicious consequence to the Trade, and greatly endangered the Lives of many of the Inhabitants of this Colony, and occasioned a very great expence to the Town of Newport in particular.

"And whereas the Laws to prevent the same, by Reason of their great Number, and the various Occasions on which they were Made, are become perplexed and intricate"—

The first section repeals all laws heretofore made relating thereto, and declares that "the following rules and orders shall for the future be kept and observed."

The first and second enactments repeat, with but slight and unimportant differences, the portions of the law of 1711. The act of 1743 enjoins—

"That the Governor, Deputy-Governor, Assistants, Justices, and Wardens, as aforesaid, be, and they are hereby, empowered and directed to send a Doctor or other suitable Person to examine into and to make report to him or them, respectively, of the true state of such vessel and the people on board, at the charge of the Master or Commander of such vessel; And the Naval Officer is hereby forbid to clear out such vessel 'til said charge (having been adjusted and settled by the Town Council of the Town where such vessel shall arrive) is fully satisfied and paid.

"That the Town Council of Newport, or other Town where such vessel shall arrive, be, and they are hereby, empowered and directed forthwith to put on board such vessel some suitable Persons or Persons to secure said vessel and effectually prevent any communication therewith, at the Expence of the owners.

"That the Town Council of Newport, or other Town as aforesaid, be and they are hereby empowered and directed to confine on board said vessel, or send to some Pesthouse, or other suitable Place, all Persons, Mariners or Passengers or others, that came in said vessel, for a convenient time, until such of them as have, or are liable to have, the Small-Pox, or other infectious distemper, are perfectly recovered and cleansed from said Distemper, or have passed a suitable Quarantine, and also all other Persons that have gone on board such vessel without Licence, as aforesaid, at the charge and expence of such Persons, respectively, and also all other Persons that came in said Vessel, until they have been sufficiently aired and cleansed.

"That the Town Council of the Town where such Vessel arrives be, and they are hereby, empowered and directed to appoint two meet Persons to take effectual, that all Goods, Wares, and Merchandises imported in such vessels which they think liable to hold and communicate the infection be landed on some of the Islands in the Narragansett Bay, and exposed to the sun and air, and cleansed, not exceeding ten days, nor under six days, before they are permitted to be brought into any House, Shop, or Warehouse, other than where they are cleansed as aforesaid; and when such goods are sufficiently aired and cleansed, Said Persons shall give the Owners or Possessors

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* The naval office was established in 1682. By an act of the general assembly of that date the governor was empowered "to appoint one or more naval officers, in such place or places in this colony, as he shall think fit and needful." Their duties were "to take entries of vessels, and in all things belonging to said office, to take care that the laws relating to navigation or customs and duties on goods and merchandize be duly observed."

thereof a Certificate; and the Town Council shall allow or order said Goods to be delivered to the owner or owners thereof; And the charge and expence of landing, airing, and cleansing such Goods, Wares, and Merchandizes shall be borne by the respective Owner or Owners; and all Goods that are judged by the Town Council not liable to hold the Infection shall be delivered to the Owner or Owners without Delay and expence of airing as soon as may be consistent with the Safety of the Town in regard Parts of the Cargo. And all Goods, Wares, or Merchandize imported into any town in this Colony by Land from any place infected with the Small-Pox or other Contagious Distemper shall be aired, cleansed at the discretion of the Town Council of such Town, and at the Expence of the Owner or Owners thereof.

"That all goods imported in such vessel as aforesaid, that shall be clandestinely landed or brought into any House, Shop or Warehouse, without Certificate or allowance as aforesaid, or that shall be imported by land as aforesaid, and not cleansed or aired by order of the Town Council as aforesaid, shall be forfeited; one-third to and for the Use of the Colony and the other two-thirds to him or them that shall inform, and sue for the same in the Inferior Court of Common Pleas in the County where Such offence shall be committed; and all Assistants, Justices, and Wardens are hereby empowered and required, upon information given them, to seize and secure all such Goods, Wares, and Merchandizes in their respective Jurisdictions, until legal Trial.

"That the Town Council of Newport, or other Town as aforesaid, be and they are hereby empowered and directed to fix, settle, and adjust all Wages and Charges demanded by Persons employed by them to secure such vessel, or to air and cleanse such Goods, or to attend upon, and nurse Such Person, as aforesaid. And that if any owner, freighter, or Mariner, or Passenger as aforesaid shall refuse to pay such Wages and charges, so settled, adjusted and fixed by the Town Council, that then the Town Treasurer of such Town is hereby empowered and required to sue for and recover such Wages and charges if above Five Pounds in the Inferior Court of Common Pleas in the County where such Charges shall be adjusted and settled, and if under that Sum, then before any two Justices or Wardens, as in the Case of other Actions. And the Judges of such Court where the Action is brought, are hereby empowered to tax double costs for the Plaintiff, any law, custom or usage to the contrary, notwithstanding.

"That for the better security of the Payment of what charges may arise on the Nursing or Attendance upon any Sailor or Mariner belonging to such Vessel as aforesaid, the Master thereof is hereby required to stop payment of the wages due to such Mariner, until certified from the Town Council, that such charges are fully satisfied and paid, on penalty of paying the same so far as the Amount of the Wages so paid by him: And no court in that Colony shall make up Judgement for any such Wages, until Satisfaction be made as aforesaid; And this Act being pleaded in any Court, where such wages, if sued for by such Mariner, shall be a temporary Bar of such Action. Any Law, Usage, or Custom to the Contrary notwithstanding. And the Master or Owner of any Servant or Slaves on board such Vessels, or the Persons to whom such Slaves are consigned, shall pay all Charges, arising by them, for their Nursing and Attendance.

"That the Master of any Ship or other vessel coming into the Harbour of Newport, who shall refuse to bring to his Vessel, when the Gunner of Fort George shall fire a shot at him, shall pay Ten Shillings for the first shot and Twenty Shillings for the second, and Five Pounds for every shot afterward, to and for the use of the Colony; and three shillings to the Naval Officer as his Fee for receiving the same, who shall not clear out said Vessel till the Same is paid.

"That when the Small-Pox shall be prevalent in the Town of Boston, or in any other Town of New England, all Persons whatsoever (the Post only excepted) who shall come from such Town into the Colony, without remaining five days on the borders of this Colony, shall forfeit for such Offense Five Pounds, to and for the use of the Colony, upon legal conviction thereof before any two Assistants, or Justices of the Peace, who are hereby empowered to hear and try the same, and also to send back, or confine said Offender in some convenient Place until the term of five days be expired, after such Tryal and Judgement. And the Assistants, Justices of the Peace, or Wardens in any Town in this Colony, are hereby empowered to appoint proper persons at all Ferries or places that seem to them necessary, to examine on oath, or engagement, all persons suspected to transgress this Law, and on occasion to apprehend and bring such Offenders before said Assistants, or Justices of the Peace, or Wardens, that they may be dealt with according to Law.

"That all Persons who keep Publick Houses, or Boarders in their Houses, shall immediately acquaint the next Assistant Justice of the Peace or Warden of the Town, wherein they dwell, when any Person boarding or lodging in their house is taken sick with the Small-Pox, or other contagious distemper, or suspected to be so on the Penalty of forfeiting Five Pounds to and for the use of the Town to be recovered by the Town Treasurer before any two Assistants, Justices of the Peace, or Wardens of said Town; and the Assistant, Justice of the Peace, or Warden so notified is hereby empowered and directed to make proper examination by some Doctor or other skilful Person, and if it be the Small-Pox, or other contagious Distemper wherewith Such sick Person, is visited then immediately to set a proper guard to prevent the spreading of the infection, and to summon the Town Council of such Town, who are hereby authorized and empowered to remove said Person being an Inmate or Boarder in any house in any town in this Colony, to any such place in the said Town as they shall think the most proper to prevent the spreading of the Infection, or to continue the said Guard as aforesaid, according as to them shall seem necessary, and likewise to confine all such Persons as may be by them suspected to have taken the Distemper in some proper place till they are recovered and cleansed from the said Distemper or have performed a suitable Quarantine; and all charges arising hereby, shall be adjusted, settled, and fixed by the Town Council, and paid by the Parties respectively concerned; and upon his or their refusal, shall be sued for, and recovered by the Town Treasurer as aforesaid.

"That in case the small-pox shall break out in any house, or family in any town in the County of Newport, the Assistants, Justices of the Peace, or Wardens in said Town, together with the Town Council thereof, be and they are hereby fully empowered to remove any inhabitant of said town, visited with the Small-Pox to the Pest House in said town, or any other convenient place in order to prevent the spreading of the Infection, or otherwise at their discretion, to place a guard round the Dwelling house of the infected Person as to them shall seem necessary. Any Law, custom or usage to the Contrary notwithstanding.

"That so long as the Town Council of any town, shall think it fit to endeavour the preventing the spreading of the small-pox, no person whatsoever, under any pretence whatsoever shall presume to visit any person suspected to have the Small-pox or to go into the house where suspected Persons are confined without a License first had from the Town Council, or from one Assistant or from two or more justices of the peace or Wardens of the town on the penalty of forfeiting for every such offense ten pounds in Money of the New Tenor; one-half to and for the use of the Town where such offense is committed, and the other half to him or them that shall inform and sue for the same in the Inferior Court of Common Pleas in the County. And such Persons on information of their offense, shall be liable to be confined till they are suitably aired and cleansed, or have performed a suitable Quarantine at the discretion of the Town Council to whom complaint of the same shall be made.

"That any person and persons who shall be legally convicted of willfully and purposely Spreading the Small-Pox within this Colony, he, she, or they shall be adjudged to suffer the pains and penalty of Death, as in the case of felony, without Benefit of the Clergy. And all persons legally convicted of wickedly endeavoring to spread the same shall be sentenced to be whipped not exceeding thirty-nine lashes, and suffer six months' imprisonment, and be kept to hard labour.

"That it shall and may be lawful for any two or more Assistants, justices of the peace, or Wardens in any Town in this Colony having reason to suspect that any person or persons have endeavoured wickedly and wilfully to spread the Small-Pox in any town of this Colony, to commit such Person or persons to his Majesty's Gaol, there to remain till he, she, or they give good and sufficient Security to appear at the next General Court of Assize and General Gaol Delivery, and of their good behaviour during said time. Provided Nothing in this act shall be construed or understood to extend to such Practioners in Physick as shall be allowed by the Town Council to inoculate the said Distemper, after the said Town Council have thought fit to desist their endeavours to prevent the further spreading of said distemper."

An Act passed by the general assembly of his majesty's colony of Rhode Island, in August, 1747, modifying the mode of recovering the penalty consequent on the violation of the act of 1743, and for defraying the expense of guarding houses infested with the small-pox.

An Act In 1748 sets forth that the Small-Pox and other contagious Diseases have several times brought into this Colony by masters of Ships and other vessels coming from infected places, which have proved of pernicious consequence to the Trade, and greatly endangered the lives of many of the Inhabitants of this Colony, and occasioned a very great expense to the Town of Newport in particular.

"*Therefore be it enacted*, That no infected Vessel be anchored within one mile of any landing place under the penalty of sixty pounds; that no person shall come on shore without a proper license; that a Physician shall be sent on board to examine the vessel and crew and make a true report of the same; that the Town Council of Newport, or other town, shall have power to put a suitable person on board to prevent communication; that the said Council shall have power to confine the people on board or send them to the Pest Houses, and that all Goods arriving in such Vessels shall be properly aired and cleansed."

October, 1748: "That all the expences incurred, in consequence of said vessels, shall be at the charge of the owners.

"That all travellers coming from Boston or other town, when Small-Pox shall be prevalent there, shall remain five days on the borders of the Colony; that all Persons who keep Public Houses or Boarders in their houses, shall report when any of their Lodgers are taken ill of the Small-Pox or any other Contagious Distemper; that in cases of contagious diseases, occurring in private Houses, the Town Council of the several towns shall have authority to send the individuals so infected to the Pest House or other convenient place in said town: that Physicians refusing to perform any duty required by the Authorities to prevent the spreading of the Small-Pox, shall forfeit the sum of twelve pounds."

In October, 1751, the Hon. Stephen Hopkins represented the exposed condition of Providence with regard to the contagion of small-pox, and requested the grant of £600 from the treasury of the State for the establishment of a pest house in said town, which request was granted.

In May, 1752, "An act to prevent the small-pox from being brought into the colony by strangers and travellers coming from infected districts."

In May, 1776, the general assembly passed an act permitting inoculation for the small-pox in this colony:

"Whereas the small-pox hath made the most dreadful ravages in the army lately before Quebec, which was the principal cause of raising the blockade of that city, and there is great danger that the inhabitants of the United Colonies may, by the prevalence of that distemper, be rendered incapable of defense at a time when their safety may depend upon their most vigorous exertions;

"And whereas that distemper taken by inoculation is so easy and light, and the method of treatment so beneficial, that any number of persons inoculated are more likely to live than the same number of persons not inoculated; and as by introducing the practice of inoculation, with prudence and caution, the greater part of the male inhabitants of the colonies may soon get over that terrible disease, and the fatal consequences to be apprehended from our armies being infected therewith be averted:

"*Be it therefore enacted by the general assembly, &c.*, That one hospital may be established for inoculating for the small-pox in each county in this colony, in such town as the majority of the deputies in the county, in a meeting duly warned, shall agree upon. That the hospital in the town which shall be so agreed upon shall be fixed in some suitable and retired place in such town, under the direction of the town council or of such committee as the town shall appoint: *Provided*, Then when such hospital shall be improved for that purpose, the town shall mark off the ground round said hospital at a distance not less than two hundred yards every way therefrom, and set and maintain a sufficient guard to prevent all persons in the hospital from going beyond the limits, and all persons without from passing within one hundred yards of them without the permission of the directors of the hospital, upon the penalty of 100 pounds."

Particular attention was ordered to be devoted to airing and cleansing the clothing and bedding of the patients, and proper penalties affixed to all violations of these orders, whether arising from the carelessness of the attendants and the want of proper care on the part of physicians, and the several towns were authorized to make further necessary regulations.

In September, 1793, the town council of Newport, during the prevalence of the yellow fever, published extracts from the act of the State legislature to prevent the spreading of the small-pox and other contagious sickness in this colony. (See Newport Mercury, Tuesday, September 24, 1793.) Thus vessels infected with yellow fever, on coming from any port where that epidemic prevailed, were obliged to anchor one mile distant from a landing-place, under a penalty of £60. And public houses were warned against receiving travelers without timely and immediate notice to the assistants, justices, or wardens of the town.

On the 21st of September, 1793, the Governor of Rhode Island, Arthur Fenner, esq., issued the following proclamation: (See Newport Mercury, October 1, 1793.)

"Whereas a contagious distemper of the most malignant kind prevails in Philadelphia and the West Indies, and unless every necessary precaution is taken to prevent its being brought into the State, the lives of the good citizens thereof will be greatly endangered: I have, therefore, thought fit to issue this proclamation, earnestly recommending it to the several town councils, to all other officers, and to the citizens of this State, to use their most utmost vigilance in causing the law, to prevent the introduction and spreading of the small-pox and other contagious sickness, to be most strictly and punctually executed; more especially with respect to all vessels which shall arrive in this State from the West Indies, Philadelphia, and New York; there being reason to apprehend danger from the great intercourse between the last-mentioned place and Philadelphia. And it is expected and required of all masters of vessels, and others, coming from the said places, or from any other place infected with any contagious disorder, that they observe the said law with the greatest exactness."

An act was passed by the general assembly, in 1798, confirming the sanitary laws enacted in 1743 and 1748, and authorizing the town councils to make regulations for the preservation of the health of the inhabitants, and the governor to appoint health officers in every port deemed by him necessary, in order to visit all vessels suspected of having contagion on board, and to carry into effect the provisions of this act.

Acts have been passed in 1806, 1816, 1822, and 1840, by the general assembly, conferring from time to time on the town councils, or the board of aldermen in the several towns, sufficient authority to guard the people against contagious diseases. For the first century and a half the small-pox was the most malignant disease that invaded New England. Against the invasions of this disease the legislature in recent years has taken preventive steps, by enforcing acts for thorough vaccination, as in January, 1840, and subsequently. With regard to the yellow fever and cholera, the town councils acted efficiently, deriving their authority from the ancient laws, given here, against small-pox and other contagious diseases.

In January, 1850, Rhode Island passed laws to secure an adequate registration of births, deaths, and marriages on the recommendation of an authorized committee of the Rhode Island Medical Society. The secretary and a committee of the Rhode Island Medical Society were ordered to print the returns annually. On the establishment of the State board of health in April, 1878, the duties assigned to the secretary of state, &c., of printing the registers, have been transferred to that body. Chapters 75, 76, and 77, in the general statutes of Rhode Island, printed in Cambridge, 1872, contain the general laws passed by the State on quarantine, contagious diseases among cattle, and the registration of births, deaths, and marriages.

STATE OF RHODE ISLAND, EXECUTIVE DEPARTMENT,
*Providence, October* 12, 1881.

Dr. J. L. CABELL,
*President National Board of Health, Washington, D. C.:*

SIR: I have the honor to acknowledge receipt of your letter of the 10th instant, with inclosures, as therein stated, in reference to the quarantine limits of the city of Newport.

I have sent to Mayor Slocum a copy of your letter for his information. I presume the matter will receive prompt attention from him.

Very respectfully,

A. H. LITTLEFIELD,
*Governor.*

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# APPENDIX 7.

QUARANTINE STATION,
*Ship Island, November* 1, 1881.

Dr. T. J. TURNER, U. S. N.,
*Secretary National Board of Health, Washington D. C.:*

SIR: In compliance with your request that I should furnish at my earliest convenience a detailed report of the operations at this station during the past season, the following is most respectfully submitted:

Taking charge of this station on the 17th day of March last, I immediately began taking a complete inventory of all the government property in my charge, and on completion of the same a copy was at once forwarded to your office; a careful examination was also made of all the buildings here, and some recommendations, which I considered of importance, are now a matter of record with the Board at Washington

## BOARDING OF VESSELS.

From the time of taking charge until this date—the time covered by this report—I have boarded all vessels coming to an anchor at the Ship Island and the quarantine anchorages, and herewith present a tabulated report showing the vessels so boarded by name, nature, the day of arrival, whether quarantined or not, and when quarantined, the amount of fees collected for cost of material consumed in purification. These several fees have been deposited with the assistant treasurer of the United States at New Orleans, and original receipts for the same forwarded to you as directed.

It will be observed in reference to the tabulated report just alluded to that there were ten vessels placed in quarantine during the entire season, said vessels being from Havana, Vera Cruz, Rio de Janeiro, and Aspinwall.

The Emma Payzant, from Vera Cruz, arrived at Pensacola quarantine station about the 4th day of July, with sickness on board, which was pronounced by the quarantine physician at that station to have been yellow fever, and in consequence was dispatched to this station for treatment, arriving here on the 13th day of July. During her stay at this station I treated ten cases which I pronounced yellow fever of mild type, and the fact of the recovery of the entire number gives weight to my opinion of the type, or contradicts altogether any diagnosis of the disease; the latter does not, however, by any means follow as a logical sequence, as it is now known that during the summer of 1879 there were more than the above number of cases attended at one house in the city, New Orleans, and all recovered, the type of the disease being so mild as not to have been detected at the time by the attending physician. As I have already made a special report to you in relation to the Emma Payzant, the sickness on board, and the treatment of the vessel at this station, I will not dwell longer than to announce the belief that I am reasonably certain that the master of said vessel at the time of her discharge from quarantine was perfectly *satisfied* with the treatment which his family, the crew, and the vessel received at this station.

The Dew, in consequence of having lost two men in rapid succession during the voyage from Aspinwall to Pascagoula, was, immediately upon her arrival at the Pascagoula quarantine station, dispatched to this station by the quarantine officer of the former port, and arrived here July 23. While I could procure no absolute proof of infection on the part of this vessel, it was thought best to give the sanitary interests of the coast the benefit of all the doubt in the premises, and the vessel was treated as though *known* to have been infected. After her discharge from this quarantine station she proceeded to Pascagoula and took on a cargo of lumber without further trouble.

The Lotus having been reported as leaving Havana, bound for Mobile, with her captain and mate sick with yellow fever, on her arrival just off the bar near the Mobile quarantine station, was spoken by the Mobile quarantine physician and ordered to this station, arriving here on the 30th day of August. At the time of her arrival the mate had entirely recovered, and the captain was improving though not entirely recovered. The vessel was placed in the best sanitary condition possible at our hands, and after her discharge proceeded to Mobile and took on a cargo of lumber at the wharf, no other case of disease manifesting itself.

The Ada Barton, just prior to sailing from Havana for this port, sent her captain to the hospital sick with small-pox, where he subsequently died with that disease. On the arrival of the vessel at this port the bill of health stated that the vessel had been fumigated and the crew vaccinated. She was detained at this station a sufficient length of time to complete twelve full days from time of sailing from Havana, and no other case of disease presenting, she was thoroughly fumigated and discharged from quarantine.

In addition to the vessels mentioned on the tabulated report as having been boarded, I have *spoken* a number of vessels entering Ship-Island Channel, bound for other ports, that are not included in said report. I have boarded all vessels coming to an anchorage at the Ship Island and at this quarantine anchorage, and have endeavored to speak all others entering the channel during the daytime.

During the past season I have been compelled to decline to receive into the hospital here *surgical* cases from the shipping, as well as to furnish medical or surgical aid, for reasons that will manifestly present themselves to every member of the Board; and in one instance my conduct in such refusal was severely criticized by the captain of the vessel on which the accident occurred. The resident member of the Board in New Orleans was thoroughly acquainted with all the details of this case, and it afforded me much pleasure to state that my conduct in the entire matter was indorsed by him in unqualified terms.

## QUARANTINE REPORTS.

From the time of taking charge, up to and including Saturday, October 29, these weekly reports have been prepared and forwarded, as directed, to your office and to the resident member at New Orleans. These reports and miscellaneous correspondence has kept the honorable Board entirely posted as to the operations at this station; therefore this report can be but, as it were, a repetition of the weekly reports and correspondence alluded to.

## INTERCOURSE WITH MAINLAND.

So soon as it was reported that an infected vessel had been ordered from Pensacola quarantine station to this station, there were rumors of "trouble ahead" in relation to our future intercourse with Biloxi, and that probably we would be cut off entirely. In order to forestall such a result *before* the arrival of the infected bark Emma Payzant the sloop Annie was dispatched to Biloxi for the purpose of attending to the requirements of the station in that quarter, and three times a week the steamer ran over within one mile of Biloxi and anchored, from which point an open yawl was sent out about five hundred yards and anchored; the crew of the sloop, remaining all the time at Biloxi, then came out in an open yawl with ice, fresh meat, &c.,

placed the same in the open, empty, anchored yawl, and then retired, after which the crew of the steamer went out and brought in the yawl and contents, and steamer returned with the same to the station. These transfers were made in the open sound, and within sight of all the people of Biloxi who came to witness them, so that there was occular demonstration of the fact that there was no direct communication between the two crews. In my opinion the maintenance of intercourse with mainland is largely due to this method of making transfers.

### IMPROVEMENTS TO PROPERTY.

Since March last two railroad cars complete have been placed on the track on wharf at the west end of the island; a coal bin has also been constructed alongside the land end of the wharf, with an estimated capacity of two hundred tons; the foundations of physician's residence have been boarded up to prevent the sand flowing from the same; a kitchen built in connection with said building, and an additional cistern placed in position near the same; a brick chimney has been constructed at one end of the physician's residence, and the room at that end ceiled to render it habitable in winter. Sand hills about the premises have been cut down and the ground leveled and inclosed with a substantial wire fence. The hospital grounds have also been inclosed with wire fence and wharves constructed on both the hospital and lazaretto sides of the lagoon; the grounds of the lazeretto remain yet to be enclosed, and all the cisterns require repainting, for which work material is already on hand.

The property of the service has been carefully looked after, and is, I feel safe in asserting, in a good state of preservation.

### EMPLOYÉS.

During the entire season it became necessary to discharge but three persons—one for alcoholic intoxication, and two for insubordination—though frequent annoyances have been caused by employés retiring from the service of their own accord, and at times without any notice whatever. It occurs to the writer that the efficiency of the service would be increased by shipping all persons to be employed on vessels for the *season*, say from May to September, inclusive, instead of by the month.

In conclusion, allow me to thank you, and through you the honorable executive committee, for promptness in attention to matters connected with this station, as well as for the constant support and confidence bestowed upon me.

Most respectfully,

T. S. SCALES, M. D.,
*Superintendent.*

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## NATIONAL BOARD OF HEALTH.

## QUARANTINE STATION, SHIP ISLAND.

*List of vessels boarded at this station.*

| Name of vessel. | Nature of vessel. | | | | | | Date of arrival. | Quarantine. | | Fee collected for disinfecting material. |
|---|---|---|---|---|---|---|---|---|---|---|
| | Ship. | Bark. | Barkentine. | Brig. | Brigantine. | Schooner. | | Yes. | No. | |
| | | | | | | | 1881. | | | |
| Ella | | 1 | | | | | Mar. 23 | | 1 | |
| R. W. Wood | | 1 | | | | | April 2 | | 1 | |
| Gratia | | 1 | | | | | April 23 | | 1 | |
| Asia | | 1 | | | | | April 25 | | 1 | |
| Cuba y'Canarias | | | | 1 | | | May 2 | | 1 | |
| Sandusky | 1 | | | | | | May 4 | | 1 | |
| St. Pierre | | 1 | | | | | May 15 | | 1 | |
| Schiller | | | 1 | | | | May 19 | 1 | | $3 40 |
| Taye | | 1 | | | | | May 23 | | 1 | |
| Richard Pierce | | | 1 | | | | May 24 | 1 | | 2 50 |
| Ada Barton | | 1 | | | | | May 26 | 1 | | 6 00 |
| Pauline David | 1 | | | | | | May 29 | | 1 | |
| Urano | | 1 | | | | | June 14 | | 1 | |
| Albert Sheutz | | | 1 | | | | June 17 | | 1 | |
| Lady Dufferin | | 1 | | | | | July 7 | | 1 | |
| P. C. Peterson | | 1 | | | | | July 7 | | 1 | |

*List of vessels boarded at this station*—Continued.

| Name of vessel. | Nature of vessel. |  |  |  |  |  | Date of arrival. | Quarantine. |  | Fee collected for disinfecting material. |
|---|---|---|---|---|---|---|---|---|---|---|
|  | Ship. | Bark. | Barkentine. | Brig. | Brigantine. | Schooner. |  | Yes. | No. |  |
|  |  |  |  |  |  |  | 1181. |  |  |  |
| Nightingale | 1 |  |  |  |  |  | July 10 |  | 1 |  |
| Guldreger |  | 1 |  |  |  |  | July 10 |  | 1 |  |
| Emma Payzant |  | 1 |  |  |  |  | July 13 | 1 |  | $21 25 |
| Dew |  | 1 |  |  |  |  | July 23 | 1 |  | 7 00 |
| Able |  | 1 |  |  |  |  | July 30 |  | 1 |  |
| Branlio y'Vicinte |  |  |  |  | 1 |  | Aug. 3 | 1 |  | 3 75 |
| Kate |  | 1 |  |  |  |  | Aug. 15 |  | 1 |  |
| Hippolite B. |  | 1 |  |  |  |  | Aug. 29 | 1 |  | 5 00 |
| Vernal |  |  |  |  |  | 1 | Aug. 30 | 1 |  | 4 50 |
| Lotus |  |  | 1 |  |  |  | Aug. 30 | 1 |  | 7 50 |
| Sofia de Vila |  | 1 |  |  |  |  | Aug. 31 |  | 1 |  |
| Schiller |  |  | 1 |  |  |  | Sept. 16 | 1 |  | 5 00 |
| Indianola |  |  |  |  |  | 1 | Sept. 17 |  | 1 |  |
| Excelsior |  | 1 |  |  |  |  | Sept. 22 |  | 1 |  |
| Admiral |  |  |  |  |  | 1 | Sept. 24 |  | 1 |  |
| Branlio y'Viciente |  |  |  |  | 1 |  | Oct. 9 |  | 1 |  |
| Screumer | 1 |  |  |  |  |  | Oct. 23 |  | 1 |  |
| Total | 4 | 18 | 5 | 1 | 2 | 3 |  | 10 | 23 | 65 90 |

## APPENDIX 8.

## *REPORT OF OPERATIONS AT SAPELO QUARANTINE STATION, SEASON OF* 1881.

[DR. W. H. ELLIOTT, SUPERINTENDET.]

Instructions to open the Sapelo Quarantine Station were received April 21. From this time till the 17th of May was occupied in completing the improvements on the Gypsy, in engaging employés, and purchasing supplies. The station was reached on the 18th of May, and was declared open for the reception of vessels on the 21st, due notice being given to the municipal authorities by letter and to the public through the Savannah Morning News. The public property and the grounds at the station were found in good order. The equipment station was put in working order by erecting four tents at the north end, two for employés and two as quarters for the well, and sixteen tents at the south end, four for hospital and the rest as quarters. During the season eight temporary wooden structures were erected of the average capacity of a hospital tent. These were found necessary, as the tents were, with two exceptions, blown down in the gale in August. Two of these buildings are located at the north end, and served as residence and kitchen for the sanitary police in charge of the anchorage.

### EMPLOYÉS.

The number of employés at the opening of the station was seventeen. This number was gradually increased to twenty-six, the largest number employed during the season. The least number was thirteen, and the average for the season was about sixteen. Of the seventeen engaged in May, only five remained to the close of the season; and of those engaged subsequently, eleven remained till regularly discharged.

Up to the 1st of November there were fifteen dismissals for incompetency or misconduct, and sixteen departures; several of these being without warning or the consent of the inspector. The frequent changes in the personnel of those employed had a very injurious effect on the morale of the force, and were a constant source of anxiety and annoyance to the inspector. It was manifest that to most of them neither a definite engagement nor the oath of office had any power in restraining them from leaving or from misconduct requiring dismissal. Indeed, dismissal was not regarded as a matter of any moment, while the judicious infliction of moderate fines had a wholesome and restraining influence.

The health of those employed at the station was not so good as in the previous year. Periodic fevers prevailed generally in June and July, and to some extent during the rest of the summer and fall, this prevalence attributed in part to the clearing of underbrush and weeds, thus exposing the soil previously sheltered to the sun in the long summer days. The clearing the preceding year had not been so extensive and was done later in the season.

### VESSELS AT QUARANTINE.

The American schooner Seth W. Smith arrived at the station August 21 from the quarantine station at Brunswick, where she had been lying six days. She sailed from Sagua le Grande on the 9th instant, with two officers, five crew, and one passenger; total, eight. One of the crew was taken sick on the 10th with yellow fever, and the other four on succeeding days; attacks being rather light. The vessel arrived at the Brunswick quarantine on the 15th instant. The captain failed to mention the sickness on board, which was not detected by the pilot or health officer, and this, too, in face of the fact that the bill of health certified that she left the port of Sagua "in suspicion."

On the 17th instant the mate was taken sick, and two days later the vessel was ordered to Sapelo, where she arrived at sunset, August 21, with the mate in *articulo mortis*. At this time one of the crew was convalescing and the rest were well. The schooner was stranded by the gale of August 27; was gotten off with little or no damage, October 5, and was granted immediate pratique at Doboy, whither she proceeded on the 8th instant.

The British steamship Maharajah arrived at Sapelo August 26, being ordered from the Savannah quarantine, where she lay for one day. This vessel sailed from Fort de France, Martinique, on the 17th instant, with twenty-one persons on board. Just before sailing three cases of sickness occurred on board, believed to be yellow fever. Two of the cases were at once sent to the hospital on shore, and their further history is unknown. The third case died at sea on the 22d. This vessel brought a clean bill of health, which was retained by the authorities at Savannah. Two of the crew were taken sick off the bar at Tybee, and proved to be severe cases of yellow fever; nevertheless the pilot took the boat into local quarantine. For this action he was sentenced by the municipal authorities to two weeks' detention at the quarantine, and to pay a fine of $50. Two more cases occurred at Sapelo on the 28th and 31st instant, respectively. All four recovered. This steamer was also stranded by the gale. She was gotten off September 6; left Sapelo on the 18th, and went to the Savannah quarantine, where she was detained twelve days by the authorities.

The British barkentine Caledonia, with eight persons on board, arrived at Sapelo September 14. She sailed from Pointe à Pitre, Guadeloupe, August 24, with foul bill of health; eight deaths from yellow fever having occurred in the port and adjacent country during the week preceding her departure. She arrived at Brunswick September 5, the foul bill neither preventing the pilot from taking her in, nor the health officer from allowing her to remain at the quarantine. On the 8th instant one of the crew was taken with yellow fever. The vessel was immediately ordered to Sapelo, but the services of a tug to effect the removal could not be obtained till after a delay of five days. On arrival the case was convalescent, and no other cases of sickness occurred. The vessel was granted pratique on the 22d instant, and proceeded the next day to Brunswick, where she was allowed to proceed at once to the city.

The Spanish bark Manuel, fourteen persons, sailed from Havana on the 10th of September, with foul bill of health. At the time of sailing one of the crew had symptoms of yellow fever. Notice to this effect was sent by the National Board to the authorities of Brunswick. Pilots being cautioned, this vessel was ordered to Sapelo from off Saint Simon's Bar. She arrived the 20th instant, all well, and continued so. Pratique was granted October 1. The vessel waited at Sapelo till the morning of the 5th for a tug to tow her to sea. She sailed early on that day and reached Saint Simon's Bar about 2 p. m. Shortly after, while in charge of the pilot, and in consequence of incorrect orders from him, she went ashore on the south breakers, and went to pieces during the night, which was characterized by the highest tide of the year and a moderate gale. Two of the crew were lost. The rest reached the shore in boats. The pilot was tried and deprived of his license, and the captain of the bark exonerated from all blame in the matter.

The British steamship Brinkburn, twenty-nine persons, sailed from Saint Thomas, West Indies, on the 22d of September, with clean bill of health, dated 20th instant. On the night of the 21st the second officer was taken with yellow fever; was sick all the voyage, though not confined to bed. The steamer arrived off Tybee and was ordered to Sapelo; she arrived on the 27th instant. Two persons were taken sick, one on the 26th and one on the morning of the 27th, with yellow fever, making four in all. They were removed to hospital immediately upon arrival, where the officer died on the 30th instant. The rest recovered. The vessel was granted pratique on the 5th of October; sailed on the 8th for Savannah, where she was ordered to Charleston by her owners; arrived on the 9th, and was detained at quarantine sixteen days by the State board of health.

### REMARKS.

An examination of the record shows that five vessels arrived at the station. On board of these were 82 persons; of these 16 were taken with yellow fever at the port of departure or on the voyage; 3 more cases occurred at the station, 1 on the morning of arrival, 1 after a lapse of two days, and the third five days after arrival. Of the 19 cases 3 died, 1 on the voyage, 1 two hours after reaching the station, and the third in hospital three days after arrival. In the remaining 16, 2 were put ashore before sailing, and the result is unknown. Fourteen made perfect recovery, five before reaching the station.

*Results at the station.*—Ten cases treated; nine recoveries; one death.

### TREATMENT OF VESSELS AT QUARANTINE.

The mode of procedure in regard to vessels at the station was as follows:

The ship's papers and all persons on board were first examined. The sick were at once taken ashore to hospital, if their condition permitted. After an examination of the hold and other parts of the vessel, the preliminary disinfection of the vessel with sulphurous-acid gas was at once proceeded with. The hatches were left closed all night. Next morning the removal of ballast and the cleansing of the vessel was begun. As soon as access could be had to the limber strakes, they were raised, the bilge water taken out by hand-pumps and buckets until the lower floor of the vessel was dry and could be properly cleaned. Then the roof, sides, and all accessible parts of the hold were thoroughly wetted by means of force-pumps. The most of the water thus thrown in was pumped out and the second disinfection performed with burning sulphur, the quantity used being in the proportion of a pound to the ton in the case of the small vessels, which were of wood, and half that quantity in case of the large iron steamers. After the disinfection by means of sulphur, solid iron sulphate was freely sprinkled on the floor before the bilge strakes were replaced.

The same method was pursued in the cabins and other parts of the vessel, except that water was not so freely used as in the hold. Clothing was hung up on ropes in the cabins, was disinfected dry, and in many instances seriously damaged by the treatment. Particular personal attention was given to secure the thorough application of the gas to all bedding, clothing, and furniture of which cloth formed a part.

The cleansing of the vessels was the most arduous part of the work, and was done by the joint efforts of the crews and the employés at the station. In this portion of his duties your inspector met with the hearty approval and co-operation of all of the masters at the station, with a single exception.

The method usually employed for the combustion of the sulphur was as follows: The floor of the vessel was protected by iron or earth so placed as to prevent the overflow of melted sulphur. The sulphur was then placed in large iron buckets and air constantly supplied in the bottom of the bucket by means of rubber and metal pipe connected with a bellows on deck. The forced supply of air caused the quick and thorough combustion of the sulphur and forced the gas into all spaces and crevices of the vessel. The process proved equal to ridding the vessels effectually of all vermin. No case of yellow fever occurred in any persons or on any vessels after leaving the station.

In regard to ballast, I have to say that no material difficulty was met with last season, but in the absence of a wharf where new and unobjectionable ballast may be supplied, serious questions may arise. The two iron steamers were supplied with ballast, consisting of water and coal from England, both unobjectionable. The schooner had only four cords of wood, which was removed and burned. She was built to sail without ballast.

The Spanish bark had clean, hard stone, taken from a quarry near Havana, and put on board by lighters without having passed through the city. With this stone was a quantity of detritus. This was condemned and thrown overboard.

The ballast of the barkentine Caledonia consisted of clean, hard stones and clean sand. The sand was removed. The remaining stone proved sufficient to ballast the vessel after removal of the sand. Without ballast, these two vessels, which were rather crank, would have been unable to maintain the upright position, even in a quiet harbor. Should the difficulty suggested arise, I can see no way of meeting it except the troublesome and expensive one of supplying ballast by means of a flat or lighter.

In concluding this portion of my report, I have to state that Sapelo quarantine station is heartily indorsed and highly appreciated by the authorities and citizens of ports protected by it. During the period of isolation from the presence of yellow fever at the station, valuable assistance in forwarding supplies was received from Dr. James Holmes, health officer at Doboy. The certificate of the inspector always proved an immediate passport through the district under his jurisdiction.

The following recommendations for the coming season are limited to such improvements to the efficient working of the station as can be made without permanent structures on shore.

### RECOMMENDATIONS.

1. It is recommended that the cut on the route between the anchorage and the hospital be deepened sufficiently to allow the station steamer to pass at any time of tide. This cut was originally dug to the depth of seven feet below mean low water, but, owing to the soft nature of the soil, refilled immediately afterward to one foot above low water line. The mud originally placed upon the margins of the cut is now sufficiently hard to hold the soft mud if placed on the outside of it.

The necessity for this work will be shown by the statement that the steamer Gypsy, with a draft of only 3 feet, could pass through the cut for a period beginning three hours before high water and terminating two hours after, less than half of the time occupied in a rise and fall of the tide. The increase of work, loss of time, and inconvenience caused by this restriction upon the movements of the steamer and employés, need only to be mentioned to be appreciated. I mention that the cost will not exceed $1,000.

2. In order to obviate the difficulties experienced during the last two seasons from the constant changes in the *personnel* of the employés, I advise that in future the employés be regularly *sworn in for the season;* that one-half of the monthly pay be retained till the end of the season, and made by contract subject to deduction for misconduct.

Should these suggestions be contrary to the regulations of the Treasury Department, the only other method of procuring faithful and efficient employés known to the inspector is by raising the rate of pay sufficiently to secure men of better average class than that heretofore employed. I remark in this connection that sailors have proved more useful than other classes at the station, as many of them are acclimated to yellow fever and have the requisite training for cleansing vessels, &c., and also much of the work on shore.

3. I think that much of the sickness which prevailed so generally at the station during the last season was due in part to the lack of ice. This article was transported from Savannah with great difficulty in limited quantities for the use of the sick, but none was furnished to employés, nor was it possible for them to obtain it with the means at their command. It is believed that the free use of ice would conduce to the health and comfort of all, and in the event of the sick unexpectedly arriving would be had without the delay of sending for it. It is therefore recommended that a small brick ice-house be erected and stored at the opening of the season, and that ice be regularly issued. Estimated cost, $500.

4. I recommend that your inspector be authorized to ascertain if a steam tug can be found, which will serve the purpose of a general quarantine station better than the one now in possession of the board. The fact that the shore equipment of the station is deficient in wharves, buildings, &c., renders a suitable steamer all the more necessary to the efficiency of the station.

The Gypsy was not built for the service, and was purchased only because the limited time in which the station was inaugurated would not allow a search for a steamer better adapted to the work required. The experience of the past two years, but more especially of the past season, in the treatment of infected vessels, has demonstrated the following defects in the steamer:

There are no adequate or comfortable quarters for inspector, crew, or sick. The vessel is devoid of limber-holes, has spaces which are inaccessible without destruction of essential parts; the waste oil from the machinery cannot be excluded from the bilge water, and no amount of care and attention has proved equal to the task of keeping the vessel clean. With this character of steamer I have felt obliged to either convey the sick in long-boats or attend them on board their vessels. Besides, the Gypsy was not constructed for use in salt water. She has a high pressure without condenser, and constant care is necessary to prevent the destruction of the boiler. It is usually necessary to blow out steam and refill with fresh water every time the steamer is used. The waste of steam by high pressure causes great consumption of coal without corresponding speed, the utmost attained so far being about eight miles an hour. For a quarantine service, where the distance from anchorage to hospital is several miles, and where a steamer is the only available means of obtaining supplies and keeping up communication with the outside world, a steamer is required which should be fast, built of iron, accessible in every part, and about sixty or seventy feet long, with fore and after cabins, admitting of the isolation of the sick. A surface-condensing engine would be much more economical in the consumption of fuel and adapted to use in salt water.

Should it be necessary to retain the Gypsy in the service, I recommend that her propeller, rudder, postshoe, and last half of shaft be made of composition, and that a steam-pump for throwing a stream of water aboard any vessel to be disinfected, be added to her equipment. The guards built on last year render the steamer much more comfortable, but being open underneath are unduly exposed in a sea-way and render the vessel unsafe. Boarding underneath with what are known as sponsons, would obviate the difficulty and improve the buoyancy of the steamer. In addition, some of the steam-pipes require renewal. The change in the parts of the machinery exposed to salt water is rendered advisable by the destructive corrosive action which the metal of the sheathing has upon the iron. The shoe is nearly destroyed and the other exposed parts of the machinery badly corroded.

The estimated cost of improvements and advisable repairs to the Gypsy is $900.

5. It is recommended that your inspector be authorized to purchase at the North boats and other material suitable for the use of the station, as these cannot be ordered satisfactorily by letter. The boats desired are as follows:

Two boats, about 15 feet in length, suitable for boarding vessels, at a cost of $75 each. One long-boat, 20 feet long, for bringing supplies when the steamer is not available, at a cost of $150.

There are also required six hand-pumps of various sizes for cleaning bilges.

Six hand-bellows for supplying air to sulphur-pots, and six iron buckets or pans for disinfection. Estimated cost, $100.

Two steam-gauges, one head-light, two marine clocks, one needed for the Gypsy, and will cost $50.

It is believed that all of the above-mentioned articles can be bought of better quality and at less cost in the large markets of the North than elsewhere, and that the personal attention of your inspector to the details of construction and selection of materials will conduce to the proper equipment of the station.

6. I recommend that the publication in regard to the purposes and facilities, and directions for reaching Sapelo station, for which the data were furnished last year, be issued as soon as practicable. And with a view to that end, it is suggested that the municipal authorities of the various ports be requested to make their quarantine rules and regulations at once, and furnish official copies to the Board for insertion in the publication.

I am satisfied that the majority of the masters of vessels do not know of the existence of a national quarantine station at Sapelo, and the sooner the publication is made and disseminated, the better.

7. I recommend that the Sapelo rules and regulations be presented to the State board of health of South Carolina (as that has not been done), and their indorsement requested.

8. As the authorities of the various ports in the Sapelo district declined to approve that provision of the Sapelo rules and regulations which requires that suspected vessels shall be sent to Sapelo station, it is recommended that the clause relating thereto be stricken from the rules prior to their publication. (See page 4, lines 13 to 15 inclusive of Sapelo rules and regulations.). This action of the local authorities retains to them a heavy responsibility which would otherwise rest upon the National Board; namely, the decision of the difficult question whether or not a vessel should be admitted direct to local quarantine. As I do not believe that this responsibility is duly appreciated or the dangers of confiding such questions to pilots are properly understood, I recommend that the National Board of Health issue a circular to the municipal authorities and quarantine officials of each port in the district, which shall state explicitly the opinion of the Board in regard to the dangers inherent in the system as now pursued, and shall effectually relieve the Board from any responsibility if yellow fever is imported directly through a local quarantine. The following draft of circular is appended as expressing definitely the views of the writer:

### DRAFT OF CIRCULAR.

The National Board of Health desires to call the attention of the municipal authorities and quarantine officers of the South Atlantic coast to what it deems the weak point in the system of quarantine as now administered in the Sapelo district under the combined action of national and local authority.

As a part of the system inaugurated at Sapelo station, the National Board designed that all vessels coming from the yellow-fever zone from the 1st of May to the 1st of November should report first at Sapelo station, and after examination and treatment, if necessary, proceed to port of destination; thus making the general station at Sapelo serve as an outpost or advance guard for the entire district.

As this feature of the plan was not approved by the municipal authorities interested, the clause relating thereto has been stricken from the rules and regulations for Sapelo station, and the responsibility of deciding upon the sanitary condition of vessels destined for this part of the coast has thus been voluntarily retained by the authorities of the ports.

As the question whether a vessel shall be sent to Sapelo or admitted to local quarantine must be decided outside the bar, the decision is necessarily confided to the pilots acting under instructions. For this difficult service these men have had neither education nor training, and besides are subjected to the loss of fees if the vessel is ordered to Sapelo. What with a judgment thus biased by self-interest and the well-known disposition of masters to misrepresent and make light of any sickness or other circumstances injurious to the sanitary reputation of their vessels, it is not to be expected that all dangerous vessels will be excluded from local quarantines.

The experience of the past season will show the correctness of this position. Of five vessels which were sent to Sapelo station in 1881, one was taken to local quarantine by the pilot, with bill of health marked "in suspicion," and after five cases of yellow fever had occurred during the voyage. A second was admitted with clean bill, but with one man sick, and after a death on board during the voyage. The infliction of a fine of $5 and two weeks' detention of the pilot at quarantine for disobedience of orders, had the salutary effect of excluding another vessel (5th instant) from this port with a case of fever on board.

In a third instance a vessel was admitted to local quarantine with *foul* bill of health, but all well on board. The correctness of the bill was demonstrated by the occurrence of a case of yellow fever after arrival.

In the fourth instance a telegram of warning from the National Board excluded the vessel from port of destination.

Theory indicates the weak point of the present system, and experience shows that the danger of infected vessels gaining admission to local quarantines with the necessary risk of imparting the infection to contiguous ports is no inconsiderable one.

Under these circumstances, the National Board of Health desires to call the attention of municipal authorities to the serious responsibility resting upon them in this matter, and to suggest plain and more stringent regulations for pilots, requiring them to send all vessels to Sapelo in all cases of suspicion or doubt.

Quarantine officers are recommended to send promptly to Sapelo all vessels which have improperly gained admission to their stations or been found in unsanitary condition.

# APPENDIX 9.

## *YELLOW FEVER AT KEY WEST, FLA.*

REPORT OF Dr. S. M. BEMISS, *member of the National Board of Health.*

SHIP ISLAND, *September* 29, 1881.

SIR: I respectfully offer the following report of my visit to Key West to "investigate and report in regard to the existence of yellow fever at that place":

I arrived at Key West on Wednesday, September 21. Meeting the health officer, Dr. Lester, on board the mail-boat, I requested him to report my arrival to the president of the board of health and solicit an early interview. In accordance with this request, Dr. Plummer, the president of the local board, very promptly called, and after a conference upon the subject of yellow fever in Key West and the objects of my visit, he told me that he would endeavor to get his board together and invite me to meet them and exchange views with them. On the following morning the invitation was received.

I now visited the leading physicians in the place, in order to learn the precise facts regarding the existence of yellow fever in the city.

I have examined the papers giving the history of the first three cases, and have to state that no person at all conversant with the symptoms and mode of spread of this disease will for a moment doubt that these cases were correctly diagnosed as yellow fever. It occurred, however, that the local board of health dissented from this opinion, in regard to the first case, if not to all of them. They passed a resolution revoking the authority vested in Dr. F. W. Lester to act as health officer. Dr. Lester had very promptly reported the case to the National Board of Health, and it cannot be doubted that his removal from office was in consequence of this fact. This action of the local board awakened so much distrust in places having commercial relations with Key West, and such severe criticisms from the press of other places, that, after a week or two, the board thought it better to restore Dr. Lester to his former position. In justice to Dr. Lester, it should be stated that the second and third cases occurred during the interim of his suspension from office, and this is why these cases were not officially reported by the health officer of Key West.

The local board also thought proper to adopt the policy of appointing a committee of experts, to be chosen by their president, who should determine whether Ambrose, the first victim to the disease in Key West this year, did really die of yellow fever or of some other disease.

I have also to report that upon the day of my arrival at Key West, Dr. Harris, one of the leading practitioners of the town, asked me to accompany him to see a patient whose case he had officially reported as one of yellow fever. The patient was almost moribund when I saw him, and, basing my action upon the judgment and experience of his medical attendant, I telegraphed the case as the fourth one which had occurred in Key West this summer, to the date of my visit. No case was known to exist upon the island at the time of my departure.

Pursuant to agreement, I met the local board and a number of the leading citizens of the place, and explained the policy and methods which I considered best calculated to secure a better sanitary condition of their population. The city has no financial resources or funds which might enable it to put into operation any efficient sewerage system. While a large portion of the island is sufficiently above tide-water to make an underground system available, the contrary is true in respect to a very considerable portion of the town. Surface drainage is the only method employed to rid the town of sewage filth. This must always be objectionable in latitudes and localities where frequent rains and torrid heat favor noxious exhalations. But even this method is very poorly executed in Key West. The streets are badly graded, and pools of water are met with in a majority of them. If there are ordinances requiring the removal of garbage and privy accumulations, they are not properly enforced. It may be further stated that the dwelling-houses in Key West are not constructed with reference to the sanitary well-being of their occupants. They are for the most part constructed of wood, without chimneys or any provision for fires. In a great many instances the weather-boarding is badly, if at all, protected by paint or whitewash, and the process of decay is astonishingly rapid in the almost perpetually alternating rains and sunshine of this locality.

But these trespasses against ordinary sanitary precepts have, in all probability, less to do with the occurrence of yellow fever at Key West than other circumstances now to be enumerated. Key West must be looked upon, in any sanitary sense, as one of the most important points within the boundaries of the Union. It is, as it were, a sanitary outpost where epidemic invasion is continually threatened. Its principal trade is with Havana, and the citizens are remarkably sensitive in regard to any interruption of this traffic. I found a great deal of misapprehension and unfounded opposition to the National Board of Health, on account of the alleged fact that an inspector sent to Key West by the National Board had stated to the citizens that the only means of keeping out yellow fever was by the abandonment of all trade with Cuba, and that the National Board favored such a course. It would, in my opinion, be extremely unwise to attempt to place inhibitory restraints upon commerce between Key West and the West India Islands. The passage is so short, and the opportunities to evade severe quarantine restrictions so facile, that too stringent rules would in all probability result in evil instead of good. In my opinion a skillful inspection of all vessels, persons, and material arriving from infected ports is more likely to prove efficacious in preventing the importation of yellow fever than quarantines of mere detention. Of course those engaged in this service should have authority to hold suspected vessels, persons, or material under observeration sufficiently long to practice the most thorough cleansing and disinfection, and if unacclimated persons be found among the crew or passengers, sufficiently long to terminate the usual period of incubation of yellow fever—say five days.

But whatever methods of prevention or quarantine may be adopted, there is continual danger that yellow-fever cases will occur in Key West. Some of the citizens, and perhaps some of the physicians, believe the disease either to be indigenous or permanently domiciled there. But this theory, which has been often applied to other portions of the United States, melts away and becomes untenable wherever proper means of prevention are employed. I know of no reason in the sanitary history of Key West furnishing grounds for a belief that it is an exception to this statement.

I think I hazard nothing in saying that when a case of yellow fever occurs in Key West the greatest obstacle in the way of attempts to stamp it out is found in the difficulty of securing prompt and competent isolation. Frequent contact with yellow fever seems to render people utterly indifferent to it, in so far as it concerns themselves, and they are prone to lose sight of the worst characteristic the disease possesses—its spreading nature. No restraints were fixed against visits to Ambrose's room after his physicians had pronounced the case to be one of yellow fever. Indeed it was affirmed in my presence that when the president or the local board questioned the diagnosis, he invited non-professional persons to visit the case and give their opinions of its character. The same lack of proper precautions regarding the body, clothing, and surroundings of the patient was continued after his death. These circumstances are not mentioned in a censorious spirit, for the preventability of yellow-fever epidemics is too recently established as a fact to justify censure against those who may never have witnessed well-directed and practical efforts to prevent the spread of the disease.

I found quarantine enforced very strictly against Key West by most of the Gulf towns. The cases were located quite a distance from the shipping. Their number and situation were not such as to justify such stringent quarantines, if all the boards of health of these various places, together with that of Key West, had been working harmoniously under the rules of the National Board of Health, or upon any uniform and well-adjusted system.

There was an apparent lack of confidence in the candor of the local board, and wherever this exists imagination and rumor are liable to picture matters tenfold worse than the reality. If the local board, in similar emergencies in future, adopt the inspection system under the supervision of the National Board of Heath, quarantine against Key West may be avoided, while the interests of public health shall suffer no detriment. One, or at most two, well-experienced and vigilant inspectors should have been able to prevent the transportation of infected persons or material from Key West to other points as effectually as it was done in Tennessee and Louisiana in 1879.

Communities which establish quarantine restrictions against other places are too often accused of hostile feelings and intentions. I found nothing of the sort in Florida, but much apprehension—probably more than the facts justified; but the point of trouble at last was a doubt whether all the facts were given into their possession.

The circumstances at Key West were not such as to render it proper or necessary for the National Board to offer aid. Up to the present time the local board has not asked or in any manner invited the co-operation or aid of the National Board. I, however, gave an assurance to the local board that the National Board would cheerfully and promptly comply with the law whenever in the future its aid and co-operation should be formally solicited.

Key West has a delightful climate, and a location which, under proper sanitary measures, should give it great immunity from those diseases which do not, like yellow fever, follow the channels of commerce and human intercourse. Wisdom and care in the selection of persons to serve on her boards of health; wisdom, vigilance, and care in preventing the introduction of infectious diseases, and in arresting their spread if cases do occur, and the utmost candor toward her neighbors must insure her prosperity in the future.

Very respectfully,

S. M. BEMISS,
*Member of the National Board of Health.*

Dr. T. J. TURNER, *Secretary.*

# APPENDIX 10.

## *REPORT, RIVER INSPECTION SERVICE,* 1881.

DR. F. W. REILLY, *Superintendent.*

OFFICE OF THE SUPERINTENDENT,
RIVER INSPECTION SERVICE, N. B. H.,
*Memphis, Tenn., October* 15, 1881.

SIR: In accordance with telegraphed instructions from the secretary, April 26, the Mississippi River inspection service of the National Board of Health was resumed for the season of 1881 by the assignment, on May 1, of Inspector S. H. Collins to duty at Vicksburg, Miss., and of Inspector W. B. Winn at Memphis, Tenn., under the rules and regulations of the previous season. The stations at Bayou Sara, La., and Cairo, Ill., were not included in these instructions, and nothing in the health conditions of the valley occurred during the season to warrant their re-establishment. Inspections were at first ordered to be continued until June 30 only, but this was subsequently modified so as to continue until September 30.

During this period, beginning May 1 and closing September 30, a total of 1,203 craft of all descriptions, carrying 42,401 persons—passengers, officers, and crews—were inspected at the Vicksburg and Memphis stations, being an increase of inspection at these stations of 373 vessels and 5,621 persons, as compared with the season of 1880. Following is a detailed tabular statement of inspections:

*Tabular statement of inspections.*

| Inspections. | At Memphis. | At Vicksburg. | Total. |
|---|---|---|---|
| Passenger and freight packets | 149 | 142 | 291 |
| Officers and crews on same | 9,089 | 9,230 | 18,319 |
| Passengers on same | 10,977 | 9,372 | 20,349 |
| Tow-boats | 61 | 53 | 114 |
| Officers and crews on same | 1,997 | 1,736 | 3,733 |
| Barges, flat-boats, &c | 427 | 371 | 798 |
| Total | 22,700 | 20,904 | 43,604 |
| Tonnage: | | | |
| Passenger and freight packets | 141,822 67 | 202,026 24 | 343,848 91 |
| Tow-boats | 27,442 11 | 23,929 83 | 51,371 94 |
| Barges, flat-boats, &c | 316,074 47 | 234,574 83 | 550,649 30 |
| Total tonnage inspected | 485,339 25 | 460,530 90 | 945,870 15 |

RESULTS OF INSPECTIONS—SANITARY CONDITION OF BOATS—HEALTH OF PERSONS.

Although at the beginning of the season the inspections disclosed some defects in the sanitary condition of vessels, there was found a marked improvement in this respect as compared with their condition at the opening of the previous season. It is evident that the work of the service in this direction is permanent. There is a continuous attention now paid throughout the entire year to the cleansing and purification of holds and bilges, to the policing of deck-rooms, crews' quarters, water-closets, &c., and to the general sanitary policing of the vessel. With the exception of an occasional admonition concerning a foul bilge (only two instances reported), the compulsory destruction of one lot of filthy deck-hands' bedding and one dirty crews' water-closet, ordered cleansed and disinfected, there was found nothing objectionable in the condition of any of the regular passenger and freight packets. Three tow-boats required the bilge pumped out and holds disinfected, and six barges passed up with decomposing grain under the dunnage and in the limbers. All reasonable effort, however, seemed to be made to comply with the requests of the inspectors, and every facility was afforded by the officers for securing thorough inspections. Occasional instances occurred (eleven in all) in which boats cleared from New Orleans without notifying the inspectors at that port, and, consequently, without being inspected; and in which both barges and inhabited flat-boats were added to tows in that port after the inspector had completed his inspection and furnished his certificate. In all such cases a thorough primary inspection was made on arrival at the first station (Vicksburg), and the facts were duly noted on the certificate. No boat is believed to have passed beyond the Vicksburg station the condition of which, either in persons on board, cargo, or belongings, offered any menace to the public health.

The morbidity figures do not vary materially from those of the previous season, when 118 cases of sickness were found among the 82,045 persons inspected at New Orleans, Bayou Sara, Vicksburg, and Memphis, being in the ratio of 1.44 per thousand. This season 61 cases were found among 42,401 persons inspected at Vicksburg and Memphis only, a proportion of 1.43 per thousand. The gravity of the cases, however, seems to have been greater in the latter than in the former year, since in 1880 no deaths were reported as coming within the purview of the service, while during the season just closed there were three deaths *en voyage* and two at the stations. Following is a table of the sickness reported, together with the number and causes of deaths:

| Diseases. | Cases. |
|---|---|
| Malarial fevers, remittent and intermittent* | 32 |
| Malarial toxæmia | 6 |
| Congestive malarial fever† | 5 |
| Typhoid fever‡ | 2 |
| Jaundice | 1 |
| Diarrhœa, acute | 5 |
| Diarrhœa, chronic | 1 |
| Dysentery | 3 |
| Cholera morbus | 1 |
| Cholera infantum | 1 |
| Consumption§ | 1 |
| Laryngitis, chronic | 1 |
| Alcoholism | 1 |
| Unknown‖ | 1 |
| Total | 61 |

*One death from *remittent malarial fever* during voyage; body transshipped at Memphis for Louisville by rail.

†Two deaths from *congestive malarial fever*; one during voyage, buried on the river bank above Greenville, Miss.; one at Memphis inspection station, forty hours after reception; buried at the station.

‡One death from *typhoid fever* on sixth day after reception at Memphis station; buried at station.

§One death from *consumption* during the voyage, below Vicksburg, and body landed at that port.

‖"Unknown," one man missing from boat on arrival at Vicksburg station; reported to have been put ashore sick at Gretna, La., opposite New Orleans.

In addition to the foregoing there were found "on board" one corpse, with certificate from the New Orleans inspector; cause of death, "entero-colitis"; one from Helena, Ark., with permit from Memphis board of health; cause of death, "dysentery"; and one from Walnut Bend, Ark., referred to Memphis board of health; cause of death not stated.

### SICKNESS AT THE STATIONS.

Owing to the high stage of water in the Mississippi on the 1st of May it was found impracticable to establish the stations on shore in the localities previously occupied.

Inspections were therefore made until May 17 from the wharf-boat at Vicksburg, and until May 25 at Fort Pickering for Memphis, during which periods the inspectors and employés were quartered on the hospital barges. On the above dates, respectively, the permanent stations were occupied, but the sites proved unhealthy, and neither station was free from sickness at any time during the season. Inspector Collins was first attacked at the Vicksburg station, and was relieved by Inspector Winn on the 7th of June, Collins being transferred to Memphis. His illness continuing, Dr. Collins resigned June 20, and was succeeded by Dr. H. S. Ashe, of Memphis, appointed inspector June 21. On the 28th of June Dr. Winn was prostrated, and was removed to the city hospital at Vicksburg, Inspector Ashe being sent to fill his place, while the superintendent took charge of the Memphis station until the arrival of Dr. Fayette Dunlap, of Danville, Ky., appointed inspector July 1. Inspector Ashe, who had already contracted malarial fever at the Memphis station, was seized with congestive chills soon after his arrival at the Vicksburg station, and continued to suffer from intermittent malarial fever until so far incapacitated for duty that he tendered his resignation on the 15th of August, to take effect on the 31st. August 15 he was relieved by the superintendent, who took charge of the Memphis station until the return, September 1, of Inspector Dunlap from below, the Vicksburg station on that date being placed in charge of Dr. Rudolph Matas, of New Orleans, appointed inspector August 24. No further changes were made during the remainder of the season, but Dr. Dunlap was attacked with malarial fever immediately upon his arrival at his home in Kentucky. The frequently-recurring disabilities of the inspectors at the Vicksburg stations caused a few days' suspension of inspections at that point during the latter part of July, but they were resumed August 1, and continued thereafter uninterruptedly until the close of the season. Not a single employé altogether escaped illness at either station during some portion of the season, the sickness being almost exclusively confined to the malarial fevers.

### THE SANITARY FLEET.

There have been added to the sanitary fleet since the close of last season three new hospital barges and one disinfecting barge. The hospital barges consist of substantially-constructed hulls 72 feet long, 20 feet beam, and 3 feet depth of hold, with four-foot guards all around, making the available deck surface 28x80 feet, or 2,240 square feet. Upon this deck is a hospital ward 20x45 feet, with accommodations for twelve patients, giving to each 75 square feet of floor space and 900 cubic feet of air space. Though below the minimum air space for hospitals on shore, this is believed to be ample for these isolated wards, which are open on all sides and are ventilated by 10-inch openings at the floor and eaves, extending entirely around the ward, and by a four-foot sky-light, with pivoted sash, running the full length of the room. In addition to these provisions are two ventilating shafts in each ward, extending from the hold through the roof, so arranged as to be operated by the heat from stoves (in suitable weather), and calculated to thoroughly ventilate the ward independently of other means. As a measure of precaution in the case of delirious patients, all windows and doors are securely protected by heavy wire screens. The wards are furnished with iron-frame hospital-cots, woven-wire bottoms, 36-inch cotton-top mattresses, and all other necessary appliances. Provision is also made for the isolation of any desired number of beds without obstructing light or ventilation. At the forward end of each barge, on the port side, is the nurses' room, and on the larboard side is the kitchen, while at the stern, on the port side, are the dispensary and store-room, and on the larboard side are the bath-room and water-closet. The roof of the ward is protected from the sun by heavy canvas awnings, and similar protection is furnished for each side along the guards. A proper equipment of anchors, lines, pumps, hose, &c., is also furnished.

The disinfecting barge consists of a hull 16x48 feet, with 3 feet depth of hold. An attendants' room and store-room (combined) is situated forward, and the large iron disinfecting tank, formerly carried on the steamer Benner, is located in the roofed space amidships. A suitable boiler for generating steam for this tank has also been provided. Commodious bunkers for the storage of coal, disinfectants, &c., occupy the hold.

The hospital hulk, J. W. Vanzant, has been brought down from Cairo, and is now moored with the rest of the fleet at Fort Pickering. This hulk has been thoroughly overhauled and repaired, and the framework for a large hospital-ward and the necessary offices has been erected, ready for bulkheading and roofing. For the present the boat is being used for storage purposes.

The sanitary fleet now embraces—

One sanitary patrol steamer, the H. H. Benner;
Three steam launches, the Lookout, Picket, and Sentinel;
Three hospital barges;
One disinfecting barge; and
One sanitary store-boat, the J. W. Vanzant.

Upon this fleet is now stored all of the property of the National Board of Health in the Mississippi Valley north of New Orleans, except one hundred and fifty barrels of sulphur at Cairo, Ill., and certain articles at Jackson, Meridian, and Concordia, Miss., which were distributed to those places during the epidemic of 1879. At this date the sulphur is being stored in the basement of the custom-house at Cairo, through the courtesy of the Hon. George Fisher, surveyor of customs at that port, and the remaining articles, in accordance with the instructions of the executive committee, are being shipped to the sanitary fleet, for storage, under the supervision of Dr. Wirt Johnston, secretary of the Mississippi State board of health. A detailed report and inventory of the property now stored at Fort Pickering was forwarded to the Secretary's office on the 30th ultimo.

### PUBLIC CONFIDENCE IN THE SERVICE.

Cause for congratulation is to be found in the substantial absence during the past season of alarming rumors and consequent excitement and interference with travel and traffic. The only occurrence worthy of mention in this connection was the sickness on a towboat which arrived at Memphis one Sunday afternoon in July. She had several cases of malarial fever on board, and had lost her second engineer from the same cause just before arriving at the inspection station below the city. The landing of this corpse for transshipment to Louisville, and of three of the sick men for hospital treatment, caused considerable gossip among the idlers on the levee and the street-corner quidnuncs; and before nightfall a well-developed "yellow fever scare" threatened, which, however, was promptly arrested by the publication of the following official statement:

[Official.]

MEMPHIS, *July* 11, 1881.

The towboat John A. Woods, which arrived at this port last evening, had four men on board sick with intermittent fever, and one convalescing from the same. One man died on Saturday night. This man, Thomas Kunkle, had been sick between five and six weeks. The history of the case and examination of the body point to remittent fever, without proper treatment and care, as the cause of death.

There is absolutely nothing in the case of this boat to warrant any suspicion of contagious disease. If there had been any doubt as to the nature of the sickness on board she would not have been allowed to pass the station at President's Island. Her sanitary history is known and a matter of record during the entire trip.

Notwithstanding our confidence in the vigilance and competency of the inspectors below Vicksburg and at President's Island, the undersigned verified the certificate of inspection and its indorsements by personally boarding and examining this boat and her people as well as the dead body, after she was moored at the coal fleet above the city.

Any statements or representations conflicting with the above are false, and their circulation is mischievous, if not malicious.

G. B. THORNTON, M. D.,  
*President Board of Health.*  
F. W. REILLY, M. D.,  
*Superintendent River Inspection Service, National Board of Health.*

Of course, there have been some rumors and an occasional telegram, stating that yellow fever was reported at such and such a place, and asking particulars. The reply from the superintendent's office to such queries has, in every case, been accepted as conclusive; and it is believed that the various communities in the valley place the most implicit confidence in the vigilance and efficiency of the river inspection service.

Cordial co-operation and assistance have been extended to the service and its officers by the health and municipal authorities along the river, as well as by the various State boards of health. This is also true, with hardly an exception, of the masters and others officers of boats upon the river. These have, as a rule, evinced a cheerful desire to comply with the requirements and regulations, and have readily accepted and acted upon the suggestions or advice of the inspectors. Substantial appreciation of the service has been especially manifested by the management of the various Anchor lines of packets of the Saint Louis and Mississippi Valley Transportation Company, and of the Brown & Jones Coal Companies, which organizations have in many ways facilitated the work of the service.

The labors and responsibilities of the superintendent have been materially lightened by the counsel and advice of the resident member of the board at Memphis, Dr. R. W. Mitchell, to whom the existence and success of the river inspection service are so largely due.

I have the honor to be, sir, very respectfully, your obedient servant,

F. W. REILLY, M. D.,  
*Superintendent River Inspection Service.*

DR. THOS. J. TURNER, U. S. N.,  
*Secretary National Board of Health, Washington, D. C.*

# APPENDIX 11.

## *REPORT OF STANFORD E. CHAILLÉ, M. D., SUPERVISING INSPECTOR NATIONAL BOARD OF HEALTH.*

OFFICE OF THE SUPERVISING INSPECTOR AT NEW ORLEANS
OF THE NATIONAL BOARD OF HEALTH,
*New Orleans, La., October* 12, 1881.

Dr. T. J. TURNER,
*Secretary National Board of Health:*

SIR: Experience has amply proved that New Orleans is pre-eminently liable to receive and to disseminate the infection of yellow fever, and, since this city is the fifth port in the United States in respect to the amount of its shipping, and probably unsurpassed in the number of its river-craft, it is of great importance in reference to all portable diseases. For these reasons I have entered into the consideration of more numerous details and at greater length than would otherwise have been deemed desirable in such a report as the one now respectfully submitted.

Appointed March 3, 1881, and assigned to duty April 26, my general instructions, dated April 28, were received May 2, and published for the information of the public May 4. Before considering these instructions, with the measures adopted for their execution and the results thereof, it is necessary, for their appreciation, to record the official history of sanitary matters in New Orleans for a few months prior to the issue of these instructions. This historical record will also throw light on the questions which have given rise to differences of opinion in regard to the administration of sanitary affairs in the State of Louisiana.

The following three questions may be thus stated:

First. Shall suspicious cases of yellow fever be promptly reported to the exposed neighboring States, or shall all suspicions be suppressed until the State board has given official assurance of the unquestionable existence of yellow fever; and, as an indispensable sequence of this question, this secondary question follows: Shall other States be permitted by Louisiana to have a representative acceptable to themselves located in New Orleans, and provided by the State authorities with every attainable facility to procure the information necessary for him promptly to warn those whom he represents of threatened danger, thereby enabling them to adopt such measures of self-protection as they may see fit?

Second. Shall other States be permitted by Louisiana to have their own representatives to give them timely information of both present and future risks of infection located not only in New Orleans but also at those State quarantine stations which are the danger outposts of adjacent States as well as of New Orleans?

Third. Ought Louisiana, regardless of the reasonable fears and expressed wishes of neighboring States, to persist in allowing *infected* vessels to enter the Mississippi River, thereby endangering many vessels and persons, before said vessels have been disinfected at the Ship Island quarantine station provided by the National Board of Health as a refuge for all such vessels destined to any of its adjacent ports?

### I.—HISTORICAL RECORD FROM SEPTEMBER, 1880, TO APRIL 28, 1881.

In respect to the public notification of the existence of yellow fever in New Orleans, the Louisiana State board has pledged itself several times in such terms as it did on September 23, 1880, when it was "*Resolved,* That as this board has *solemnly pledged itself to promptly* communicate to the country the existence within our city and State of *any* epidemic or contagious diseases, it requests the press of the United States not to attach any credence to any report in relation to the public health of our city or State that does not bear the official sanction of this board."

It is not believed that history can furnish a single instance in which similar pledges, by the authorities of any habitually infected place, have ever had the effect above requested or have ever secured the confidence of adjacent communities occasionally but not habitually infected. In this instance there was ample evidence that the neighbors of New Orleans would not be satisfied with anything less than an agent located in New Orleans to represent them there, and by timely warning enable them to protect themselves from its infection. On December 9 and 10, 1880, the "Sanitary Council of the Mississippi Valley," then in annual session at New Orleans, gave to this view the following expression:

"Whereas our people habitually view with distrust all announcements and sanitary acts of local boards, when those acts and announcements are of a character to affect the commercial interests of the locality directly concerned: *Resolved,* &c., &c.

"And whereas there is unfortunately a want of confidence with regard to the prompt furnishing of information by the health authorities of New Orleans with reference to infectious and contagious diseases:

"Therefore,

"*Resolved*, That in the opinion of this council it would undoubtedly tend to the restoration of confidence if the State board of health would request the National Board of Health to place an inspector at the quarantine station and one in New Orleans, who shall have access to the records of the board of health, and be furnished every facility for obtaining reliable information with regard to all cases deemed suspicious, and especially with regard to yellow fever."

This action of the sanitary council was vehemently denounced at the meeting of the State board on February 10, 1881, and great indignation was expressed in reference to an inspector or representative in New Orleans of the National Board of Health, with such privileges as are referred to in the above resolution, and to his assignment to duty as a so-called "spy" upon the board and its members.

On February 19, Dr. Cabell, president National Board of Health, wrote to the president of the State board inquiring whether said board would accede to two propositions, both as above, viz, the assignment to duty by the National Board of Health of an agent in New Orleans and of an inspector at the Mississippi River quarantine station, with adequate facilities for the discharge of their duties (see Appendix 1). This official letter of inquiry was not submitted to the State board until March 10, the date of its first regular monthly meeting after the receipt of said letter. In the mean time the executive committee of the New Orleans Auxiliary Sanitary Association adopted, on February 26, the following resolutions:

"Whereas the Sanitary Council of the Mississippi Valley, composed of the members of the boards of health and of the sanitary officers of the States and municipalities adjacent to and in closest relations with New Orleans, has requested the Louisiana State board of health to invite a representative of the National Board of Health to attend all the meetings of the said Louisiana State board of health, and to have free access to all its sources of information concerning the sanitary condition of New Orleans and its vicinity during the season of danger from yellow fever, and another representative to be stationed at the Mississippi River quarantine station during the same period and with similar privileges; and

"Whereas it is evident that only by compliance with this request that unreasonable apprehensions of danger can be anticipated, and premature and unnecessary restrictions upon commercial and personal intercourse with New Orleans be prevented; and

"Whereas large allowance should be made by New Orleans for the easily-excited fears of those communities whose protection against yellow fever is supposed to depend to a considerable extent upon early and accurate information concerning its appearance and progress in this city and neighborhood, and that every rational concession should be made to secure their confidence and good will:

"*Resolved*, That the Louisiana State board of health be urgently requested to reconsider their late action in regard to this question, and to acquiesce in what has been asked by the Sanitary Council of the Mississippi Valley."

A lengthy debate on the resolutions followed. Mr. Edward Booth opposed the resolutions, he being a member of the State board of health. Messrs. Charles A. Whitney, Joseph Bowling, Henry Ginder, George Horter, Charles Clinton, and Edward Fenner, spoke in favor of their adoption. The resolutions were adopted, Mr. Booth being the only vote in the negative.

Mr. Henry Ginder offered the following resolution, which was adopted:

"*Resolved*, That the New Orleans Auxiliary Sanitary Association, in behalf of the commercial and moneyed interests of the city of New Orleans, do hereby request the State board of health of Louisiana to call a special meeting of their board at as early a date as will permit their action on the resolution passed at the regular meeting of the executive committee of the New Orleans Auxiliary Sanitary Association, held February 26, 1881, to be presented to the convention of the Sanitary Council of the Mississippi Valley on March 11, 1881" [or, as it should have been, April 21, 1881].

The above resolutions, first published on February 27, were republished in the newspapers of March 13, with the signatures thereto appended of some eight hundred of the most respectable firms and citizens of New Orleans.

On March 10, previous to the republication of the above resolutions with their influential indorsement, the State board adopted, in response to the brief and simple propositions of President Cabell, and of the Auxiliary Sanitary Association, the lengthy replies cited in Appendix 2. To these eight whereases, four resolutions, and four propositions the president of the State board added, on March 22, an open letter to the president of the New Orleans Auxiliary Sanitary Association, which letter occupied four columns of fine print in a daily newspaper.

The following points in said letter deserve recording: Respecting an agent in New Orleans of the National Board of Health "the board of health of the State of Louisiana has never denied free access to all its sources of information concerning the sanitary condition of New Orleans during the season of danger from yellow fever, nor during any other season of the year." "No board of so-called experts, and no member, agent, or employé of the National Board of Health can have any legal, or exclusive, or even constructive right to investigate the cases of the licensed practitioners of medicine." "The board of health has held that, before announcing to the world the first case or cases of yellow fever, the subject should be investigated and discussed, and that the annunciation of the existence of so decided a pestilence as yellow fever should be based upon undisputable facts." *

Respecting an inspector of the National Board of Health at the Mississippi River quarantine station, it was held that the present agitation of the questions relating to quarantine during the winter and spring months "will tend to excite alarm and distrust in surrounding States, and may lead to the arbitrary establishment of quarantine against New Orleans, without any just cause, at an early period of the summer." And the favor requested was objected to, because such an inspector would have no "power for good," and because "the National Board offers no substantial aid, but simply desires to be admitted at the quarantine station as an *investigator and judge* of the mode in which the legally constituted authorities of Louisiana perform their duties." On the above two subjects no passages have been found more definite than those cited.

Finally, the letter of President Jones opposes at length the proposition that infected vessels should not be permitted to enter the Mississippi River until they have been thoroughly disinfected at the Ship Island quarantine station of the National Board of Health. This proposition was first made by the National Board to the Louisiana State board on April 10, 1880, was promptly rejected, and in the annual report for 1880 of the latter board was severely denounced as one of "the preposterous schemes of the National Board of Health." This letter and the action of the State board, cited in Appendix 2, gave rise to much public dissatisfaction, as shown by the following evidence: On March 29, the official journal of the State, the Democrat, declared that Dr. Jones's letter was "an evasion of the issue;" that his view that the State board "possesses the confidence of the people at large" was "a delusion" of Dr. Jones alone; and that inasmuch as "we must make up our minds to the presence of the National Board of Health in the persons of its inspectors and other representatives, shall we have relations of candor, good feeling, and courtesy with them, or shall we, by a policy of jealousy, churlishness, and general folly force them into an attitude of distrust and antagonism?" And the people were advised to request the president and his supporting majority of the board to resign.

Further, on April 2, the New Orleans Auxiliary Sanitary Association, having failed in its appeal of February 26, to the State board, adopted an address to the governor of Louisiana (see Appendix 3), appealing to him for the exercise of his superior authority to grant the two requests made by the Sanitary Council of the Mississippi Valley as formulated more definitely in the letter of February 19, of the president of the National Board of Health (see Appendix 1). It was urged that the State board should "revise its former action and grant, *without reservation*, the reasonable requests which have been made." This address to the governor stated: "You must have observed, if you carefully read the four closely-printed columns over the signature of the president of the board of health, that the plain and reasonable requests made by the Sanitary Council of the Mississippi Valley, and the other organizations already mentioned [the New Orleans Chamber of Commerce and the Medical and Surgical Associaciation], have been carefully evaded, the generous and catholic spirit of the board of health paraded in glowing colors, and imaginary legal difficulties made to assume insuperable proportions. For the purpose of aiding the board in the solution of these grave legal questions we have taken the liberty to submit the same to several distinguished members of the New Orleans bar, and have the pleasure of herewith appending their replies." These replies were all to the effect that the legal difficulties were "imaginary," and they were signed by all, it is believed, to whom the questions were submitted, viz, by one ex-associate justice of the United States Supreme Court, by three ex-associates justices of the Louisiana supreme court, by one ex-Senator of the United States, by two other lawyers of the highest local reputation. (See Appendix 3.)

At the two succeeding meetings of the State board the following resolutions were adopted: On April 14, it was "*Resolved*, That this board concurs in the opinion of some of the river States, that the National Board would do well to commence its river and railroad inspections on or about the 1st of May; and that this board cordially indorses the invitation, already extended by its president, to such inspector or inspectors as may be commissioned by the National Board of Health to occupy the commodious room adjacent to and in communication with the rooms and offices of this board at the State capitol; and that the inspector or inspectors aforesaid are requested and urged to be present as auditors and spectators at the meetings of this board, with a view to give efficiency to the wishes of the National Board of Health, expressed through its president, Dr. Cabell, under date of February 19, viz: 'That it may have adequate facilities for obtaining the information necessary to enable its inspectors to furnish positive and trustworthy certificates.'" At its next meeting, on April 19, the State board adopted the three following important resolutions:

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* The present generation in the Mississippi Valley is not likely to forget that while in 1878 there was not a certified death by yellow fever in New Orleans until July 21, yet that there had been unreported suspicious cases and deaths during the preceding three weeks at least, and that the tow-boat John D. Porter, which left New Orleans as early as July 18, had on board 26 cases and 14 deaths by yellow fever between said city and Gallipolis, Ohio. The great additional devastation attributed to this boat was registered by Port Gibson and Vicksburg, Miss., by Hickman, Ky., and by Gallipolis, Ohio. This sad incident is only one of many others which teach the lesson that *prompt warning* should be given, *even of suspicious cases*, to at least those sanitary authorities interested. The ethics of all civilized nations now adopt as an axiom the principle that, in a conflict between public health and commerce, precedence must be given the former.

"In order to allay apprehension in the public mind in the city and surrounding country, and to secure a correct report of the first case or cases of yellow fever which may occur in this city or within the jurisdiction of the State board of health—

"*Be it resolved*, That an agent of the National Board, to be stationed in New Orleans, shall have access to the daily reports received by the State board, and of sickness when reports of sickness are made; and that whenever the agent of the National Board or the health authorities of this State receive information of the alleged existence of one or more cases of disease of a doubtful or suspicious character as to its being infectious, the State board agrees to send one of its officers, who, together with the agent of the National Board, shall investigate the case, the two parties reporting the results to their respective boards. In case the two parties disagree, a third physician, acceptable to the two parties, shall be selected by them as umpire. A majority report shall be final, and reported as such to the National Board in cipher. The two inspectors, as appointed, should have thorough knowledge of all diseases of the Lower Mississippi Valley, and especially of yellow fever, and should be personably acceptable to the board, in order to secure friendly relations and useful co-operation, and it shall be the duty of said local inspectors of the National Board of Health to be present at all meetings of the local board.

"*Be it further resolved*, That the president of this board be requested to transmit a copy of these resolutions to the president of the National Board, and to the president of the sanitary council of the Mississippi Valley."

It was also on April 19—

"*Resolved*, That this board is of opinion that it is without power to nominate or appoint any Mississippi quarantine station-inspector whatever, and refers the matter of such nomination and appointment to his excellency the governor."

On this last subject, it is observable, in Appendix 1, which contains all the official correspondence on the subject, that there never was any question as to the "nomination and appointment" of an inspector of the National Board of Health by either the State board or the governor, but the question was simply whether the National Board of Health would be permitted to station at the Mississippi River quarantine its own nominee and appointee, "for purposes of observation and inquiry," and with "the privilege of inspecting, in company with the [State] quarantine officer, all vessels arriving at the station."* Appendix 1 shows further that, acting on the above resolution, the president of the National Board of Health applied directly to the governor of Louisiana on May 17, and called his attention thereto; that Dr. S. M. Bemiss, resident member of the National Board of Health, again solicited the governor's attention to the same subject on May 26, and, finally, that the application first made to the State board on February 19, did not receive a favorable answer until June 4.

In the mean time the sanitary council of the Mississippi Valley held its annual session on April 21, and adopted among other resolutions the four following, bearing directly on the subjects now under consideration:

"*Resolved*, That the experience of the past teaches that the quarantine of that [the Gulf] coast, and especially that on the Lower Mississippi, cannot be relied on to prevent the introduction of yellow fever into the valley of the Mississippi, and that, therefore, immediate measures should be taken to so improve their management that all the resources of science and of human skill should be applied to prevent another invasion of yellow fever through that channel.

"*Resolved*, That the sanitary council of the Mississippi Valley reaffirm the action taken at its December [1880] meeting in New Orleans, and demands that the Louisiana board of health invite the appointment and maintenance by the National Board of Health of inspectors at New Orleans, at Port Eads, and at the Mississippi quarantine station, and announces that in the event of any failure on the part of the said State board of Louisiana to act in good faith toward said inspectors, the boards of health represented in this council will be compelled to take into their own hands the protection of the health of their own people.

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* Hence, this was the proposition really rejected for lack of power, and yet on a subsequent occasion, September 15, 1881, and in a different issue, the president of the State board cited the various laws of Louisiana, which sustained the opinion of the lawyers consulted by the *Auxiliary Sanitary Association*, and in proof that "the board of health was placed *absolutely* and *unconditionally* by the general assembly of the State of Louisiana in charge of the Mississippi quarantine station, and of all others within the limits of the State." (See Appendix 8.)

"*Resolved*, That this council being firmly convinced that the safety of New Orleans, as well as of the valley, lies in the rigid exclusion of infected ships from the Lower Mississippi, strenuously urges upon the State board of health of Louisiana a modification of 'section 6' of its rules and regulations for the government of quarantine officers and stations, &c., so as to read: SEC. 6. All vessels from ports in which yellow fever is prevailing, or from ports where contagious or infectious diseases are reported to exist, shall be inspected at Port Eads. If any such be found to be infected, or furnish reasonable ground for suspicion of infection, such vessels shall not be allowed to pass Port Eads northwise except upon presentation of a certificate of inspection from the Ship Island quarantine station of the National Board of Health setting forth that the vessel has been subjected to the proper treatment, and is free from liability of conveying contagion.*

"*Resolved*, That this council condemns all methods of suppression and secrecy with reference to information of contagious or infectious diseases, therefore discountenances the use of cipher telegrams. But in the event of danger from such diseases at any point in the Mississippi Valley, it is the duty of the executive officer of the health organization of such place to fully and promptly advise the proper authorities at all the threatened points."

On June 9, the State board vehemently protested against the above action of the sanitary council.

Having concluded the historical record of those official events which served as a preface to my duties, and to my general instructions, these and their results can now be duly appreciated.

### II.—GENERAL INSTRUCTIONS OF APRIL 28, 1881.

These instructions, of which a copy is appended as Appendix 4 to this report, appointed me the "representative and chief executive agent in New Orleans" of the National Board of Health, with the title of supervising inspector. They required, in the first place, as my primary duty, "to obtain the earliest possible information of the existence of yellow fever in New Orleans or its vicinity"; in the next place, to secure between New Orleans and other points, whether the former should or should not be free from infection, as uninterrupted commercial intercourse as the protection of the latter from infection might render practicable; and, in the last place, "in case of appearance of yellow fever in New Orleans, to co-operate in every way to limit the spread of the disease and to stamp it out if possible." These three duties require consideration, however little will be needed concerning the last two, since no yellow fever infection appeared, either to be stamped out or to interrupt commerce.

#### OBTAINING INFORMATION OF THE EXISTENCE OF YELLOW FEVER.

To accomplish this duty, indispensable to the validity of my own river and railroad sanitary certificates and to the protection both of public health and commerce, the adoption of three measures was directed. First, the reception of reports from an inspector of the National Board of Health at the Mississippi River quarantine station; second, prompt information from the State board of all cases of yellow fever and suspicious cases of fever; third, the same from all other sanitary and medical organizations, as also from physicians individually.

Reports from the quarantine inspector were not received until June 5, as his assignment to duty was not authorized by Louisiana until June 4, for reasons already stated and to be found in Appendix 1. Since June 5 the required reports have been received.

In order to secure prompt information of all cases of yellow fever and suspicious cases of fever, I was instructed to present to the State board the following proposition: "That all reports of deaths and the original returns made by the attending physician, of doubtful and suspicious cases, made to the Louisiana State board or to any member thereof, shall be communicated to you at once, whether they may have been formally presented to a meeting of the State board and entered on its files or not, and that if any of these cases shall appear to you to be of a sufficiently doubtful or suspicious character to demand it, you will, upon notifying the proper officer of the

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* The regulation of the Louisiana State board did, and does still, read as follows: "SEC. 6. All vessels from ports in which yellow fever is prevailing, or from ports where other contagious or infectious diseases are reported to exist, shall be detained at quarantine stations for observation, disinfection, purification, and fumigation, not less than seventy-two hours, or for such length of time as the board of health may determine."

State board, be permitted to investigate the case in connection with such person or persons as may be appointed to accompany you by the State board." This important proposition was on May 19 unanimously adopted by the Louisiana State board (see Appendix 5). In connection with this proposition, the State board was solicited to agree that in the event of a difference of opinion in the diagnosis of doubtful cases of yellow fever between the agents of the National and State boards together with any umpire they might select, the different opinions should be reported to both boards and not the opinion solely of the majority. This proposition was not agreed to, as may be seen in Appendix 5. However, prior to the unanimous vote on this proposition, the representative of the National Board of Health stated that he wished it distinctly understood that he should obey his instructions and in all cases report his own opinion; but he would at the same time very willingly report any opinion differing from his own, whether said opinion was that of a majority or a minority. Having made this point clearly understood, the subsequent adoption of the first proposition was regarded as practically conceding the point at issue. It is, none the less, evident that the failure of the State board to agree distinctly to this second proposition may hereafter give rise to dissension.

As an additional means of securing prompt information of all cases of yellow fever or suspicious cases of fever, I was instructed "to endeavor to secure the co-operation of other sanitary and medical organizations" than the State board, and also of "the physicians of New Orleans, and of the river parishes below New Orleans." In order to execute this duty a circular requesting the aforesaid co-operation, was read before the State board, was not objected to, and was issued on May 24 (see Appendix 6). This circular was directed to organizations and physicians in New Orleans, and to physicians residing in the river parishes below New Orleans, in parishes on the Texas Railroad, and for the most part in the vicinity of the Atchafalaya quarantine station, and in the counties of Mississippi traversed by the railroad to Mobile. It was distributed to the following places in the following number, and written answers promising the solicited co-operation were received from the number stated:

| Locality. | Number of circulars distributed. | Number of favorable answers. |
|---|---|---|
| New Orleans | 226 | 84 |
| Saint Bernard and Plaquemine Parishes, between New Orleans and Port Eads | 11 | 7 |
| La Fourche and Saint Mary Parishes, between New Orleans and Texas | 19 | 15 |
| Gulf Coast of Mississippi, between New Orleans and Mobile | 16 | 12 |
| Total | 272 | 118 |

It deserves notice that while three-fourths of the country physicians promised co-operation, less than one-third of those residing in the city returned favorable written replies. This was probably due, in large measure, to the following causes: Some physicians believe that yellow fever originates here spontaneously, and that present sanitary organizations cannot prevent its occurrence; some are inimical to the National Board, some to all boards of health; and some are influenced by a considerable fraction of the community, which from interest or other motive opposes all quarantine or other restrictions on commerce.

The failure of so large a proportion of the physicians of New Orleans to promise their co-operation with the representative of the National Board of Health would not have been a cause for anxiety, provided that all were in the habit of reporting to the State board of health, as required by an ordinance of the city, which the president of the State board very commendably distributed on May 1 to those whom it concerns. This ordinance is as follows: "All practitioners of medicine, masters of any water-craft, hotel, boarding orlodging-house keepers, principals or masters of any public or private school, the chief officer or persons in charge of any public institution of charity or of punishment, and heads of families are hereby required to report, within twenty-four hours, to the office of the board of health all cases within their cognizance of Asiatic cholera, leprosy, yellow fever, typhus or ship fever, diphtheria, malignant scarlet fever, small-pox, varioloid, trichiniasis, or any other case that may at any time be specified by the board of health." It is well known, however, that this ordinance is not obeyed by all, not even by all physicians, hence the effort to secure information additional to that promised by the State board, and hence the failure of so many city physicians to promise this information constituted a cause for serious anxiety, that the first cases of yellow fever might occur without the knowledge of any sanitary officers. Among the favorable answers from city physicians many were very gratifying, since they expressed hearty approval and cordial co-operation. One respondent, a creole physician of long experience and repute, replied that his aid would be actively given for the sufficient reason, and apart from those urged in my circular, that he deemed it a crime to permit unacclimated strangers to visit this city without warning when there were any cases of yellow fever here.

As an additional means of securing early information of the first cases of yellow fever in New Orleans and its vicinity, letters were addressed to United States collectors of customs, requesting them to notify me promptly of the arrival of any vessels reported to have suspicious sickness on board. Favorable answers were promptly received from all to whom the request was made, viz: from General A. S. Badger, collector of the port of New Orleans, to whom the collectors not only at New Orleans, but also at Port Eads, at Southwest Pass, at Pass à l'Outre, at the Mississippi River quarantine station, at the Rigolets, and at Lookout, a few miles beyond, all report; from Mr. J. R. Jolly, collector of customs at Morgan City, to whom also report not only the vessels arriving at the Atchafalaya quarantine station, but also at other places along the south coast of Louisiana,* and from Mr. J. R. Henderson, collector of customs at Shieldsborough, or Bay Saint Louis, Mississippi, to whom also report all vessels arriving at Ship Island and other places along the Gulf coast of the State of Mississippi.†

All these measures for securing prompt information were in practical operation by June 5, when the inspector of the National Board of Health arrived at the Mississippi River quarantine station. From this date great confidence was felt, notwithstanding the fear that some of the first cases of the dreaded fever might occur in New Orleans without the knowledge of any sanitary officers; yet, that the disease could not make such progress as to seriously endanger other States without my knowledge and their consequent warning.

An additional measure for securing information deserves notice. On April 14 the State board resolved that the inspector or inspectors of the National Board "were requested and urged to be present as auditors and spectators at the meetings of this board"; and it further resolved, on April 19, that "it shall be the duty of said local inspector of the National Board of Health to be present at *all meetings* of the local board." On this subject I was instructed "to use my own discretion in the matter." My discretion prompted me to attend on three occasions only. On two of these occasions I was treated personally with great courtesy, and given officially every desirable privilege. On the third occasion, an executive session on August 3, I was not permitted by the State board to exercise my discretion, and I have since been officially informed "that the board has decided that no one except those belonging to its own organization can be admitted to its executive sessions." It was my discretion to attend said executive session, because I had good reason to believe that it was to be held for the express purpose of determining an issue with the National Board; and the above decision of the State board was given in answer specially to my question whether the privilege would be allowed me of attending those executive sessions which might be called specially to consider subjects in which the National Board was directly involved. I had hoped that, by explanations in my power alone to give, I might, if present, be enabled to promote harmony between both boards, and I had no other motive.

In concluding this subject of the attendance of your representative in the meetings of the State board, it may be well to say that the chief aid desired of the State by the National Board is prompt information of the earliest cases of yellow fever or of suspicious cases of fever, and that this is not likely to be any better secured by attendance on said meetings, for the president has repeatedly promised that he would give such information. If your representative had the assurance that he would be granted the privilege of a voice on all occasions, when questions clearly involving the duties and interests of the National Board were under discussion, then his attendance on such occasions would, no doubt, tend to prevent useless misunderstandings, to inspire mutual respect for honest differences of opinion, and to promote the harmony so very desirable.

### ISOLATION, DISINFECTION, ETC., FOR STAMPING OUT YELLOW FEVER.

In respect to the first cases or suspected cases of yellow fever, I was also instructed "to co-operate in every way with the health authorities of the city" in stamping out the disease if possible, and in order to accomplish this, "to secure isolation, systematic disinfection, &c." Fortunately I was spared this duty, and fortunately for my relief from anxiety my responsibility in this matter would have been subordinate to that of the State board. However, for the benefit of the future, the following facts should be understood: In the first place, it is all-important that the very earliest cases, however slightly sick, should be promptly reported to and taken in hand by the sanitary officers; these requirements are very liable not to be fulfilled. In the next place, efficient isolation and disinfection of families and houses must in this country depend, in large measure, upon the willingness of the afflicted families and of their friends to give their co-operation, and also upon public sentiment representing the the value of these measures. Until sanitary officers can obtain these supports, in perfecting all measures for isolation and disinfection, their frequent failure must be expected, and prove their execution faulty rather than that the measures themselves are valueless, as is too often inferred. These impediments to success tend to render laws the best in theory very inefficient in practice. Our law is the city ordinance No. 6046, of July 8, 1879, and it reads: "The board of health may, at its discretion, regulate or *prevent access to or egress from*, or cause to be vacated, any infected building, water-craft, place, or locality; or cause to be fumigated, or otherwise disinfected, any infected building or water-craft whenever, in the opinion of said board, such action shall be deemed necessary to prevent the spread of *any* dangerous and infectious diseases." And "the board of health may disinfect any infected clothing, bedding, or other substances whenever, in the discretion of said board, such action shall be deemed necessary to prevent the spread of disease."

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* Calcasieu Pass and Cameron.

† Pascagoula, Pearlington, Pass Christian, &c.

### SHIP ISLAND QUARANTINE.

On this subject, my general instructions directed me "to endeavor to secure the co-operation of the Louisiana State board of health" in obtaining the result, "considered highly desirable by the National Board of Health, that infected ships should be as far as possible excluded from the Mississippi River." The measures by which it was proposed to secure this result were those recommended on April 21 by the sanitary council of the Mississippi Valley, and already cited in this report. The action taken by me to fulfill my instructions and the unsuccessful issue thereof are fully recorded in Appendix 5.

The principle that "infected ships should be as far as possible excluded from the Mississippi River" is so unquestionably sound that it has been advocated even by Dr. J. Jones, the ablest, most persistent, and most influential opponent of the measure proposed for its execution. Dr. Jones, who became president of the Louisiana State board, April 8, 1880, urged, in February, 1879, as follows: "Quarantine should not only command all the outlets and inlets to New Orleans, but *all vessels from infected ports* should be *entirely excluded*, or else the cargoes should be landed at the quarantine station, and should be thoroughly fumigated and then transferred to lighters to be transmitted to the city. Upon no consideration should *a vessel from an infected port* be allowed to come up to the port of New Orleans." "An imperfect quarantine, such as now exists [1878–'79] at the outlets of the Mississippi, has been and will be a sham and delusion. The question of the foreign and domestic origin of yellow fever should be determined by an *absolute* quarantine."*

In addition to the facts presented in Appendix 5, the following bear upon the extent of the commercial interests involved in the question at issue. During the five years, 1876–1880, the average annual arrivals in the Mississippi River was 1,103 vessels, and of these the annual average number detained at the quarantine station was 153. This last average represents the number of vessels from at least May 1 to November 1 from all ports infected and even suspected of infection. The number of these 153 vessels arriving really infected, so far as sanitarians could determine, has not for years past exceeded six; there was in 1880 none, or one at the utmost, the Excelsior, and in 1881 only two, the insignificant barks España and Cristina, which combined were only about 1,000 tonnage.

No doubt is entertained that New Orleans, and therefore its neighbors, would lessen the number of annual risks of infection if such infected vessels were forbidden to enter the Mississippi River, and were forced first to proceed to the refuge for them at Ship Island. If this policy were once established, and due notice given thereof, two good results would at once follow: First, infected vessels bound for New Orleans would sail direct for Ship Island, whereby most of them would avoid the 90 miles detour from Port Eads to Ship Island; second, all vessels bound to New Orleans from infected ports would be forced by pecuniary interests to adopt all the sanitary precautions calculated to protect them from infection, whereby the number of arrivals of infected vessels would soon be much diminished.

In order to secure the important information so difficult to obtain as to what vessels from infected ports are really infected, captains and crews cannot be at all trusted, nor as a rule, either local boards of health or United States consuls. Trustworthy sanitary officers, stationed at infected ports, are indispensable. Dr. D. M. Burgess, anitary Inspector at Havana, has well illustrated the usefulness of his service. But he import trade of New Orleans from the constantly infected ports of Rio and Vera ruz is much more important than that of Havana, and New Orleans has the right to xpect that it should be as well protected by the National Board from the dangers of the atter ports as from those of Havana. In case the Ship Island policy should ever be stablished, sanitary inspectors at foreign ports would not only aid in detecting what essels *were* infected, but would also warn those bound for New Orleans that they must irst proceed to the refuge provided for them at said island.

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* See page 616, vol. vi, new series, New Orleans Medical and Surgical Journal.

If the policy advocated respecting the national quarantine station at Ship Island s calculated to diminish the risks of infection, how much more important than in the past becomes the adoption of this policy for the future. New Orleans is now rejoicing in its prospects of unprecedented prosperity. The annual increase in the density of its population, in the number of its unacclimated inhabitants, and in the extent of its commerce with infected ports, must constantly increase the risks and dangers of its own infection; while at the same time the increasing commerce of the Mississippi River and the greatly increasing facilities for rapid railroad communication with every part of our continent will increase, *pari passu*, the risks and dangers of distributing this infection.

Having reviewed the chief points of my general instructions, consideration will now be given more especially to the sanitary work done.

## III.—THE INSPECTION SERVICE OF 1881.

When assigned to duty on April 26, authority was given to appoint two sanitary inspectors and two sanitary policemen for the river service. Drs. P. B. McCutchon and F. W. Parham were appointed inspectors on April 27, and assigned to duty on May 1; the two sanitary policemen, though selected, were held in abeyance for assignment to duty until need for their service should arise, which need did not occur.

On May 20 Drs. L. F. Salomon, J. M. Watkins, and P. S. Carrington were appointed inspectors for the railroad service, one for each of our three railroads, viz, the "Chicago, Saint Louis & New Orleans," the "Louisville & Nashville" (via Mobile), and the "Louisiana & Texas."

The agents of these roads, Mr. J. C. Clark, Mr. J. T. Harahan, and Messrs. C. A. Whitney and A. C. Hutchinson, responded in the most cordial and generous manner to the solicitation, to defray the expenses of these inspections, avowed their determination to support the National Board of Health, their perfect confidence in its local agents, and their willingness to be guided in the matter entirely by Dr. S. M. Bemiss, resident member, and Dr. S. E. Chaillé, the local agent and representative of the National Board. Restricting themselves to the single objection that they hoped the expenses would not be imposed until Drs. B. and C. deemed it necessary, it was decided by them, and subsequently approved by the National Board, that the railroad service should not be inaugurated until the occurence of one of two contingencies, viz, either the existence of yellow fever in New Orleans or the demand of communities on the route of the railroads. Since yellow fever did not occur, and since no communities on the aforesaid routes requested railroad inspections, except the Tennessee State board of health, the railroad service was not inaugurated except in compliance with said request. This was received on August 16, and on the 17th Drs. Salomon and Watkins were on duty for the two roads which traverse Tennessee. There have been no inspections on the Louisiana & Texas Railroad.

On June 4 the consent of his excellency L. A. Wiltz, governor of Louisiana, to station an inspector of the National Board of Health at the Mississippi River quarantine station, was received, and on June 5 Dr. G. F. Patton, who had been previously appointed, was assigned to duty, arriving at his post on the same day. On July 1, the steam-launch Lookout, which at my request had been transferred from Cairo to New Orleans on June 17, was forwarded to the Mississippi quarantine station. Its constant service has been indispensable to Inspector Patton, and has required two employés, viz., an engineer and a fireman, at a total expense of about $100 per month.

The employment of a clerk having been found indispensable, Dr. William Martin, who served as an inspector of the National Board of Health both in 1879 and 1880, consented to accept the position, has been on duty since May 2, and has rendered valuable service both to the resident member of the Board and to myself.

The above completes the list of all officers and employés in the service of the Board at New Orleans and its vicinity from April 26 to October 1, 1881. All were retired from active service on September 30 with the exception of myself and clerk, who were authorized to continue on duty, if the closing of the service and the completion of official reports should require it, to October 15.

The total expense to October 1 was $5,516.13, and will not equal to October 15 $6,000, of which about $1,800 were expended for the quarantine service. It is not believed that the service in New Orleans can, even in the healthiest years, ever be discharged in a manner satisfactory to adjacent States with a less numerous corps or at less expense. In fact, if the expense of three railroad inspectors from May to October is to be borne, as I think it should be, by the United States, if the quarantine service is to begin May 1, instead of June 5, as it did this year, and if the necessary office-rooms are to be paid for, as was not required this year, then the least annual expense would fall little short of $10,000. This would, of course, be much increased in yellow-fever years.

For the posts which were filled there were three times as many applicants as offices. In making appointments preference was given to those applicants who had already served most satisfactorily, and who were acceptable both to the resident member of the National Board and to the president of the State board.

It was very difficult to fill suitably the inspectorship at the Mississippi River quarantine station. The location of this post is not agreeable, the occupant is deprived socially and professionally of all advantages, its responsibilities are very burdensome, and its opportunities for dissension and exposure to unfavorable criticism numerous. This post specially demands integrity, capacity, firmness of character, quarantine experience, and a reputation commanding professional and public confidence. These requisites for fitness are difficult to find even among physicians advanced in life, none of whom, if really suitable for the place, are likely to accept it for the salary paid. Only three physicians whom I was willing to appoint were found, and these consented to accept with reluctance. The names of these three were submitted to the president of the State board and subsequently to the resident physician at the Mississippi River quarantine station, who is, under the law of Louisiana, an appointee not of the State board but of the governor. Both of these officers, while admitting that all three of the nominees were good men, expressed a decided preference for Dr. G. F. Patton, formerly in the service of the State at the same station, who was thereupon very gladly given the appointment. He has discharged his disagreeable and responsible duties to my satisfaction, and deserves special consideration. (See Appendix 7.)

To him and to every officer reporting to me cordial thanks are due for zealous co-operation. Each discharged not simply the regular duty assigned him, but has proved his willingness to do anything whatever deemed by me likely to promote the general good of the service. No officer could desire a better corps of subordinates.

While the inspection service required during the present year—extraordinarily, because totally exempt from yellow fever—only six officers and three employés, I was upon early application therefor authorized to appoint, in case it should be deemed necessary, not only two sanitary policemen for the river service, as already mentioned, but also three additional inspectors for the three railroads, additional to the three first authorized; two for the two "basins" or city harbors of the two canals to Lake Pontchartrain, by which during the past year 3,335 vessels, averaging about 26¼ tons each, entered the very heart of this city; and two inspectors, with four sanitary policeman, for such service in disinfection and isolation as the development of cases of yellow fever might render necessary. Thus, had yellow fever occurred, there had been selected and would have been on duty fourteen sanitary inspectors and six policemen, prepared to use every practicable means to protect adjacent States from infection by New Orleans, and to aid the State board in its contest against the infection in this city itself. It is believed that, should a serious emergency arise, not less than fifteen sanitary inspectors and an equal or greater number of sanitary policemen would find abundant occupation, and should be authorized.

From April 26 to date the supervising inspector has been uninterruptedly at his post, except on May 8, when, in company with Dr. Folsom, member of the National Board of Health, and with Dr. Jones, president of the State board, the Mississippi River quarantine station was inspected; and from May 13 to 16, during which time the river service, &c., at Memphis was inspected. in company with Drs. Folsom and Mitchell, members of the National Board of Health, and Dr. Reilly, superintendent of the river service above New Orleans.

Some consideration of the general facts concerning each service will now be given.

### THE MISSISSIPPI RIVER QUARANTINE SERVICE.

During the present year the exceptional precaution was taken by the State board to detain and disinfect all vessels from Rio from March 1, a precaution due no doubt to last year's experience with the Excelsior. However, of the three gubernatorial proclamations, which were issued on the recommendation of the State board, the first was not published until April 22. This ordered the detention at quarantine for not less than three full days of all vessels from Rio, Havana, Vera Cruz, and Aspinwall; but the State board has the power, and exercises it, of adding any infected ports to those which may be proclaimed. The second proclamation, published June 16, extended after June 30 the existing three days' detention to ten days, and Aspinwall was omitted, in the absence of all evidence that it was infected. The third proclamation, published September 16, reduced after October 15 the ten days' detention to three days. Not only were vessels from the proclaimed ports quarantined, but also those from all Cuban ports, from Saint Thomas, and from the ports extending from Tampico to the Isthmus of Panama, thus including ports not probably infected, though suspected.

. It deserves notice that the interval between the publication of the proclamations and the dates of their execution varied from only nine days to four weeks, an interval too brief for the interests of commerce; also, that while a detention for less than ten days of vessels many days at sea would theoretically suffice, yet that ten full days' detention was probably a wise precaution, in view of the present impracticability of unloading, disinfecting, and reloading vessels with desirable thoroughness and promptness.

Other commendible precautions of the State board, which would have been more commendable if some had been earlier announced, deserve reporting. On July 7 it "*Resolved*, That any port in which an infectious disease is officially known to prevail shall be put among the proclaimed ports as soon as such information may come to the knowledge of this board."

On April 29 Dr. J. Holt, city sanitary inspector, was appointed "deputy inspector of shipping in the port of New Orleans," with the duties wisely established by the present board on April 22, 1880. Inspector Holt was also ordered that "the ships bringing cargoes of coffee must be fumigated at the wharf and a second fumigation must be performed in the warehouses receiving the coffee." On August 11 the city sanitary inspectors, six in number, "were required to visit all ships within their respective districts three times a week."

On August 30 public attention was called to a city ordinance of 1870, to the effect that "no case of disease shall be removed from any vessel in the port of New Orleans to any house, residence, or hospital in the city without a written permit from the president of the board of health, under a penalty of a fine of $50 for each and every offense."

As has been stated, the average annual number of vessels quarantined at the all-important Mississippi River station has, for the five past years, been 153. During the service of Inspector Patton there were 63 during the 111 days, June 5 to September 30.

The risks of foreign infection through the two other State quarantine stations, viz, the Rigolets, of Lake Pontchartrain, and the Atchafalaya station, near Morgan City, are remarkably few, as illustrated by the following facts: During the year ending August 31, 1881, there entered the port of New Orleans by the Rigolets from 1,300 to 1,800 schooners and steamboats, but of these there were only three from all foreign ports, and these three were all from Tuxpan, Mexico, and in August. But while the risks of introducing foreign infection are so slight, the risks of conveying infection from New Orleans to other States via the Rigolets, and to other ports of Louisiana via Lake Pontchartrain, would be very numerous; for during the aforesaid year there were from 1,300 to 1,800, for the most part dirty little schooners and steamboats, which cleared from New Orleans for the ports of other States, chiefly of Mississippi, Alabama, and Florida, and from 1,500 to 2,000 cleared for places in Louisiana on the north coast of Lake Pontchartrain. The average number of clearances during the months of danger was as great as during the balance of the year.

As to the Atchafalaya station, there entered Morgan City, or Brashear, during the year, 320 steamers and 85 schooners; of these there were none from foreign ports except steamers from Vera Cruz and the Mexican coast, and of these there were none from May to November, as they are habitually withdrawn during the quarantine.

As is well known, the practical difficulties of rendering *absolutely* perfect the quarantine of a great commercial port which has many avenues of entrance are at present insurmountable. The utmost which can be reasonably hoped for is to cut off an enormous proportion of the risks of infection. The Mississippi River quarantine does now, in my opinion, cut off a majority, perhaps even 90 or more out of 100 risks. During the past year it has been much improved, not only by the funds expended on it, but also by more rigid and better administration; and for this the present president and the State board deserve great credit. But it certainly has not yet become what it ought to be, as perfect as is practicable. Existing defects are sufficiently indicated in the official documents presented in Appendices 5, 7, and in the accompanying report of Inspector Patton. These defects are due, in a measure, to what may be termed inherited causes, and probably in greater measure to the very inadequate funds supplied by this State and city to the State board of health. So far as inherited causes are concerned, public opinion still continues so lax as to quarantine precautions that it much needs for its education additional epidemics or constant stimulation from without. This loose public opinion has fostered loose quarantine customs and acts. However good the will of the State board, it finds in these conditions very great obstacles to a perfect quarantine. Granting the will and all necessary laws, essentials must remain incomplete if adequate funds be not supplied. On this all-important point the State board furnished the following evidence on September 9. It appealed to the city council to give it, in addition to the $10,000 annually appropropriated, $2,500 for the expenses indispensable for the balance of this year, stating that without this its inspectors and employés could not be paid; that $1,400 were now due, with only $400 cash in hand, and that "the financial condition of the board is worse than it has been for years." This is very poor encouragement to sanguine sanitarians; but while those living in neighboring and endangered States have a right to insist on the perfecting of all measures requisite for their own protection, they may none the less be reminded, in view of the $25,000 to $35,000 provided the State board by the impoverished treasury of this city and State, and in view of the impecunious condition of their own State boards generally, that humanity in Louisiana as elsewhere sympathizes with her whom Christ protected from those about to "cast the first stone."

As fear has been entertained of the spreading of infection from the quarantine grounds to the adjacent neighborhood, and as density of the population is an important factor in solving the amount of the danger of the infection, the following facts have been gathered with considerable labor, and with, as is believed, closely approximative accuracy. The quarantine station, about 75 miles below New Orleans, is located on a very narrow strip of cleared land, only 1 to 1¼ miles wide, between the Mississippi River and the Gulf of Mexico. It is about 30 miles above the Head of the Passes of the Mississippi and 38 above Port Eads. The population from 10 miles above the quarantine station to Port Eads, that is, of the lower 48 miles of the Mississippi River, is reported to be as follows:

| | No. of inhabited houses. | White population. | | Colored population. | | Total. |
|---|---|---|---|---|---|---|
| | | Males. | Females. | Males. | Females. | |
| East bank Mississippi within 10 miles above quarrantine | 85 | 148 | 138 | 80 | 90 | 456 |
| West bank Mississippi within 10 miles above Buras post-office* | 105 | 238 | 258 | 91 | 96 | 683 |
| East bank from quarrantine to Head of Passes | 102 | 108 | 105 | 14 | 12 | 239 |
| West bank from Buras post-office to Head of Passes | 50 | 192 | 201 | 44 | 38 | 475 |
| Head of Passes, point, and both sides | ...... | 27 | 26 | ........ | .......... | 53 |
| Port Eads (South Pass) | ...... | 116 | 15 | 9 | 8 | 148 |
| Pilot Town (Southwest Pass) | ...... | 150 | 50 | 6 | 3 | 209 |
| Total | ...... | 979 | 793 | 244 | 247 | 2,263 |

* The Buras post-office, directly opposite the quarantine station, is not, properly speaking, a village, the houses averaging at this part of the river some 200 yards apart.

During the last month (September) of Inspector Patton's service certain charges, which have not been substantiated, have been made against him. The official correspondence and proceedings are recorded in Appendix 7. I have found Inspector Patton always trustworthy and obedient to his instructions, and I am confident that he would always comply with all regulations properly made known to him. It will be found in Appendix 7 that I have expressed my belief that the objections made to Inspector Patton are altogether secondary to the objections against having in future any inspector whomsoever of the National Board at the Mississippi River quarantine station.

His accompanying report contains additional facts of interest concerning specially the Mississippi River quarantine service.

### THE RIVER SERVICE.

The annual reports of the New Orleans Price Current show that during the four years, 1877-'80, the annual average of steamboats arriving at New Orleans slightly exceeded 3,000, and that the average for the five months, May to October, was 1,013. This year during the said five months there were only 203 steamboats and 208 barges inspected, for there were no orders to inspect any river craft except those which passed the Vicksburg and Memphis inspecting stations, and those steamboats (four only) which after July 18, departed for Shreveport, the three places which have in recent years been ravaged so severely. No river craft other than those mentioned cleared from New Orleans for said places nor for any places in other States via the Mississippi, with the exception of 8 steamboats and 9 barges which avoided the inspectors. During the first four months there were inspected 174 out of the 203 steamboats; however, the Price Current reports that during the same time there were 715 steamboat arrivals in

New Orleans, indicating therefore the same approximate number of departures. It thus seems that not one-fourth of the steamboats from New Orleans passed above to Vicksburg or to other States.* This indicates farther the great additional work and responsibility which would probably be imposed on the river-service inspection if New Orleans should be again invaded by yellow fever, for in such case it is probable that all endangered communities would petition the National Board of Health, as Memphis, Vicksburg, and Shreveport have this year done, to inspect all river craft destined for the landings of said communities. In such emergency it would be necessary to inspect passengers as well as freight, and it is evident that two river inspectors would not suffice for the service; for it should not be forgotten that a very great majority of steamboats leave New Orleans at 5 p. m., and that passengers board the boat during the last half hour. Hence, great difficulty would be incurred in effecting the thorough inspections necessary.

There was manifested this season great cheerfulness on the part of the agents and officers of river craft generally in voluntarily complying with the regulations of the National Board of Health, and there can be no doubt that the resulting good understanding and sanitary discipline has tended to effect results which would render the inspection service more efficient in time of real danger. As the inspectors are instructed to exercise no forcible measures, but simply to notify all departing river craft which desire sanitary certificates that they can be procured by application therefor and undergoing the necessary inspection and compliance with orders, it is gratifying to report that out of 211 steamboats destined for Memphis, Vicksburg, and Shreveport only eight refused or failed to adopt the precautions necessary to procure the certificates. Even in seasons of danger there would be no means, here in New Orleans, to correct this evil, the responsibility for which rests with those communities which permit such recalcitrant river craft to halt at their landings.

For details respecting the river service reference is respectfully made to the accompanying report of Inspectors McCutchon and Parham.

It will be as well to refer in this as in any other place to the canal service which would be desirable if New Orleans should become infected. Two canals from Lake Pontchartrain, namely the Carondelet and the New Orleans Canals, penetrate into the very heart of the most densely-populated district of this city, terminating in the so-called Old Basin and New Basin, which are, the one within one-half mile, and the other in three-quarters of a mile of the bank of the Mississippi. During the year ending August 31, 1881, 3,335 small schooners and steamboats, averaging 26½ tons each, entered these basins, and a like number, of course, departed, destined for 16 different places on Lake Pontchartrain, and for 14 different places in the United States, chiefly in Mississippi, Alabama, and Florida. via the exit from the lake to the gulf, termed the Rigolets. A number exceeding the monthly average of the 3,335 vessels cleared during the five dangerous months, May to September. These facts sufficiently indicate the need for a canal-inspection service in case New Orleans should be infected; and, since the two basins are over a mile distant from each other, the service could not be performed, as is believed, by less than two inspectors and two sanitary policemen. In addition, steamboats leave Milneburg, a lake precinct of New Orleans, several times weekly for places both on the north shore of Lake Pontchartrain and on the Gulf coast of Mississippi, Alabama, and Florida. Still farther, New Orleans has a third canal, Harvey's, which has a little commerce, on the west bank of the Mississippi, connecting this with the Gulf of Mexico.

### THE RAILROAD SERVICE.

As has been stated, this service was not established this year until August 17, only then because solicited by the Tennessee State board of health, and it was applied only to freight trains and not to passengers or passenger trains on two of our three railroads. All freight cars were properly inspected, the regulations duly enforced and cheerfully complied with, and sanitary certificates given to every freight train. So far as I am informed these certificates were never called for on the border of Tennessee or elsewhere on the route, and no officer was provided by the Tennessee State board of health, as one would suppose should have been the case, to examine carefully whether the sanitary condition of the trains justified the certificates given them. It is manifest that the efficiency of sanitary inspectors is not promoted by such a course.

If New Orleans were infected every one of its three railroads would require not less than two inspectors, one for freight, the other for passenger trains. In 1880 there was also an inspector paid by two of the three railroads, to accompany passenger trains; were this deemed necessary hereafter, then, in emergency, there would be required nine inspectors for the three present railroads. But it should not be forgotten that within a few years, even within one, the railroad communications of New Orleans will be much increased and a corresponding increase of inspection be required.

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*Reliable assurance has been given that the steamboat statistics of the New Orleans Price Current are correct, but that they include the arrivals not only from the Upper Mississippi, but also from the Lower Mississippi and by Harvey's Canal, and at Milneburg, on Lake Pontchartrain.

For details respecting the railroad service reference is respectfully made to the accompany reports of Inspectors Salomon and Watkins.

## IV.—CONSIDERATION OF SEVERAL PERTINENT SUBJECTS.

### EXEMPTION OF NEW ORLEANS FROM YELLOW FEVER IN 1881.

To this date not only no death by yellow fever has occurred, but no case, not only no case but no suspicious case, and not only no suspicious case, but no alarming rumor of one. It is doubtful whether the same good fortune has ever occurred since 1796, when New Orleans was visited by its first epidemic of yellow fever. It is certain that during the past sixty years there has been but one year, 1861, without a recorded death by yellow fever, and in said year New Orleans was blockaded by the United States on May 28, and no vessels approached New Orleans by the Mississippi until April 25, 1862, when the city was captured by the United States Navy. However, there have been several years in which one or only two deaths have been recorded, and these generally occurred in imported cases. In addition to the absence of the disease this year from New Orleans, it was likewise totally absent at all three of the Louisiana quarantine stations. Two vessels arrived at the Mississippi River quarantine station which certainly had been infected when at Havana, but the rigid precautions enforced this year on all suspected vessels were strenuously applied to these two. Although in Havana yellow fever did not prevail at as early a date, nor later to as great extent as usual, which is believed to have been due to the lack of the usual number of unacclimated immigrants, yet the disease did prevail with severity at several other of the most important Cuban ports, and of greater consequence to New Orleans, with unusual severity at Vera Cruz, owing probably to the large number of unacclimated immigrants attracted by the railroad enterprises inaugurated in Mexico. But for the quarantine restrictions on vessels from infected ports our quarantine stations, at least, would certainly not have escaped the importation of some cases.

Preceding facts tend to strengthen the view, now generally accepted, that yellow fever in New Orleans is an exotic and not an indigenous disease. This view, however, cannot yet be considered by science as fully and finally established. Therefore, it may be well to record, without discussion, other facts than those stated which bear upon the total exemption of this city in 1881 from yellow fever.

On the one hand, it is noteworthy that all places in the United States have this year escaped yellow fever, with the exception of a very few cases at its most southern port, Key West, and that, while yellow fever apparently flourishes best in humid climates and seasons, this season has been unusually dry.

On the other hand, the following facts deserve record: Local sanitation and quarantine restrictions have both been enforced more satisfactorily than usual at all yellow fever ports except Key West, where these precautions continue to be at their minimum. Though this season has been unusually dry, yet the history of yellow fever records numerous instances of the concurrence of devastating epidemics with droughts destructive to agriculture; New Orleans was severely ravaged in 1841, yet the season was exceptionally dry. The heat this season has been unusually severe, especially during June, the month in which the first cases which precede an epidemic in New Orleans are most apt to occur. Farther, in spite of the valuable improvements in local sanitation, due in large measure to our sanitary association, it can scarcely be claimed that New Orleans was so clean this season that it had not filth enough to propagate yellow fever if present or to originate it if filth can originate it. On this subject a letter, published April 6, from the president of the State board, called attention to many instances of gross local insanitation, and further stated that "the city of New Orleans is at the present moment in the same filthy condition that it was in the spring of 1878, preceding the epidemic of yellow fever which inflicted such incalculable damage upon this city and neighboring towns and villages." Farther, not only did the noses of those exposed, but also the sanitary association, protest against the foul and stinking condition of our thirty-odd miles of very inefficient drainage canals, so that two of our three most influential daily papers denounced them vigorously in editorials on August 13. Not only were heat and filth amply supplied, but the high death-rate, indicative of danger, was also added thereto. For, although the death-rate for the entire season has been favorable, yet it exceeded 40 per 1,000 for the seven dangerous and anxious weeks from May 7 to June 25. Inasmuch as there was no unusual dryness until after this date, there seem to have been present in New Orleans, at the most favorable season for yellow fever, those conditions to which has been attributed the origin of this disease in other years. On the whole, while the evidence is not conclusive, it tends none the less to strengthen the belief that New Orleans owed its total exemption in 1881 from yellow fever to the protection provided the city, indirectly as well as directly, by its quarantine stations. Due credit should also be given for the favorable influence in protecting seagoing craft from infection ascribable to the publication June 28, 1879, and to the subsequent wide distribution by the National Board of its admirable "Rules and regulations for securing the best sanitary condition of vessels, including their cargoes, passengers, and crews, coming to the United States from any foreign port where any contagious or infectious disease exists."

The proof has been conclusive that New Orleans need not annually either import or originate yellow fever, and this proof is calculated to stimulate the increased efforts and precautions necessary to test whether the disease cannot be avoided every year.

### GOOD ACCOMPLISHED BY THE NATIONAL BOARD OF HEALTH.

Granting that sanitary officers are the victims of the usual human infirmities, there can be no doubt that the two services, national and State, served to stimulate the vigilance and zeal the one of the other. Great confidence is felt and instances could be given to prove that the presence of the national inspectors did tend to increase the efficiency of the State sanitary authorities in the discharge of their duties, and that good was done thereby.

Even unfounded rumors of yellow fever inflict much injury on New Orleans, if not promptly denied by those in whom perfect confidence is felt. Such confidence was felt and expressed in the local officers of the National Board of Health even by Memphis, which is now for good reason the city most easily alarmed as to yellow fever, that there, as everywhere else, rumors were promptly suppressed as soon as official assurance was given that they were groundless. My attention was called to not less than a dozen rumors or causes for rumors, for the most part early in the season. All these proved to be groundless, and when assurance was given not only of this, but also that information would be promptly given of any which might prove to be well founded, the rumor manufacturers, silly and timid rather than malicious people, abandoned their occupation before the season was half over. There can be no doubt that many persons within and many more without New Orleans bestowed great confidence on the National Board of Health, that great satisfaction was derived by them therefrom, and that much good was done.

The agents and officers of river craft and railroads were disciplined in sanitary inspections and precautions to an extent calculated better to prepare them for compliance with the more rigid discipline which would be indispensable in a season of danger for the protection of other communities. It is believed that much good was thus effected.

Finally, the presence of the officers of the National Board of Health with the avowed intention of reporting not only the truth, but the whole truth, and of hesitating at no measure within their power calculated to protect adjacent States, has tended undoubtedly to arouse discussion, to disseminate sanitary information among the people, and to stimulate them to sanitary progress. Much good has been and will be due to this.

Discussion is the parent of that harmony of opinion which leads to efficient action, from which comes progress. To one like myself, who seeks the evidence of human progress rather from generation to generation than from year to year, and who has an experience of thirty years in New Orleans, the evidences of sanitary progress are decidedly encouraging, and especially so since 1878. However, there still remain in our public opinion such diverse views about yellow fever that there is no one view which cannot gather in its defense a very positive and turbulent crowd, and therefore there is no one view or persistent course of action which could be adopted by the National Board, or any one else, that would give universal satisfaction and escape unfavorable criticism. It is believed that the time is approaching when New Orleans and other communities will become convinced that their best policy as to transmissible epidemic diseases is to let everything be known, and that they can by this means best protect themselves from the distrust which not only originates rumors, but also inflicts panics and other evils.

### RECOMMENDATIONS.

As my recommendations have been called for, the following are respectfully submitted:

1. The funds and power which Congress may provide should be freely used in giving Louisiana the assistance much needed to perfect the quarantine stations on which the protection from yellow fever of the Mississippi Valley, as well as of New Orleans, greatly depends. If this were accomplished, their good administration secured, most of the many vessels from infected ports left to State quarantines for treatment, while the few known to be infected or suspected thereof for manifestly good reason were refused permission to enter the Mississippi unless they had been disinfected at Ship Island, then the United States would have done all in the way of quarantine precau-

tions which an enlightened government ought to do to protect from yellow fever the Mississippi Valley. Farther, whatever the National Board may be enabled to do in order to aid and co-operate with the Louisiana State board in accomplishing the commendable ends which its president recommended on September 29, 1881, should be done. These recommendations were as follows:

"Justice to the commercial community demands that rigid rules as to the length of quarantine should be fixed by legislative enactments, and not be left to the fancies of boards of health changing perpetually with political revolutions, and sometimes actuated by motives of aggrandizement for relatives and political dependents.

"According to the existing laws of Louisiana the funds derived from quarantine should be legally devoted to its maintenance, and should not be diverted by the board of health to pay either the sanitary police or the sanitary inspectors, the salaries of whom, according to the legislative acts of 1870 and 1877, are directly chargeable to the city of New Orleans.

"An advance in the quarantine system of Louisiana would be effected by the thorough equipment of the Rigolets and the Atchafalaya stations, and by the construction of a capacious and well-ventilated floating hospital for the harbor of New Orleans, to which all contagious and infectious diseases occurring amongst the shipping should be immediately transferred. It is not right that cases of small-pox, typhus, and yellow fever should be carried from the shipping into the heart of a great city, as has been the case in former times (as was done in the case of the Excelsior in 1880). There is no remedy for this evil but the establishment and thorough equipment of a floating hospital (as provided by the National Board at Vicksburg and Memphis), and the employment of a competent physician, at a liberal salary, to take charge of it and to be on duty at all times.

"This measure should be supplemented by the appointment or employment of a competent, experienced physician, whose sole duty should be the continuous inspection of the shipping and the prompt removal of all infectious diseases to the floating hospital."

2. The continuance of an inspector at the Mississippi River quarantine station is very important, and such an understanding with the State of Louisiana should be arrived at as might tend to render this assignment permanent, and if it were continuous throughout the year greater efficiency of said inspector's services would, it is believed, be better secured. No proper person can be found to accept this disagreeable post unless liberally paid, and quarters should be provided for him and his employés, either on the United States warehouse grounds, which are within those of the quarantine station and are owned by the United States, or other suitable provision should be made.

3. The most valuable import trade of New Orleans is with habitually-infected Rio; its trade with Mexico, especially with habitually-infected Vera Cruz, is more valuable than with Cuba, and is likely to be greatly increased. For these reasons it is strongly recommended that a trustworthy sanitary inspector should be posted at Rio and at Vera Cruz, to render there the same valuable services now rendered by your inspector at Havana. A statistical table is presented in Appendix 9 in illustration not only of the above facts and of the foreign commerce of New Orleans with ports rarely, if ever, infected with yellow fever, and with ports frequently or habitually infected, but also of the destructive influence of an epidemic of yellow fever (1878) on this foreign commerce.

4. For thorough efficiency in times of danger from epidemic diseases it is as important to constantly maintain the permanent nucleus of a sanitary organization, with some officers always in service, as it is important to maintain an army and a navy in time of peace. However great present ignorance and opposition, civilization must ultimately arrive at the conviction that thoroughly organized effort is as necessary to conquer disease as other enemies. Notwithstanding the popular notion to the contrary, it is very certain that very few doctors are sanitarians, and that few sanitarians in this country have the practical experience indispensable to efficient execution. This cannot be secured except through practice and discipline in actual sanitary work. Reliance in time of danger upon such inexperienced physicians as can by chance be picked up at an insignificant and temporary monthly salary is little more than blindly trusting to chance, and the results are liable ultimately to bring unmerited condemnation on any board of health forced to resort to such untrustworthy expedients. It is, therefore, recommended that whatever can be done to perfect the organization of an experienced official corps of practical sanitarians should be done.

If forced to continue to resort to present expedients, then it is recommended that all such measures be adopted as are calculated to promote the nearest attainable approximation to an experienced, and therefore permanent, corps of sanitary officers. For instance, such measures in New Orleans as follows:

The river and railroad services, as well as the quarantine service, should be instituted every year, whether healthy or not, from May 1 to October 1 at least. This I deem indispensable to secure not only the official experience, but also the cheerful and intelligent compliance of the public with the sanitary precautions necessary when danger does arise. This would now require not less than seven officers during healthy season.

It is in time of danger that disability would be most apt to occur, and also that not less than eight additional inspectors would be required; therefore, not only should the appointment (without pay until assigned to duty) of these fifteen inspectors be authorized long before danger arises, but authority should be given to select one alternate for every inspector, to supply his place in case of disability. Farther instructions should be given that, as far as practicable, the inspectors assigned to one service, as the river service, should be transferred to another service, as the railroad service, for such time as it might be necessary for each one to familiarize himself with the practical work of both services. Still farther, inspectors reserved for emergency, and all alternates, should be instructed to familiarize themselves with their duties by attendance, for sufficient time, on the work of those inspectors who may be on duty; and in appointments preference should always be given to those who gave the best proof of compliance with these instructions.

It is believed that these measures could be carried out in New Orleans provided that it was understood that the members of the corps of inspectors proposed for temporary service in periods of danger should not be compelled to leave New Orleans; for no desirable man, unless in permanent and salaried service, is likely to consent to be ordered at any moment to abandon his home.

By the adoption of the above measures there would be provided for emergencies a corps of inspectors not totally inexperienced in their duties, and ready, as is so supremely important, to enter into the discharge of these duties without a day's delay.

5. Other recommendations have been suggested in the accompanying reports of my subordinate officers, to which attention is respectfully called.

## CONCLUSION.

Your instructions "to counsel freely and fully" with Dr. S. M. Bemiss, resident member of your Board, have been cheerfully complied with, and his invariable approval of my course has been a source of great satisfaction. In no instance has there been any difference of opinion, and in every instance I have received from him valuable information and advice. My cordial thanks are also due for the encouragement and support so liberally and heartily given me by the National Board of Health and its officers. To these evidences of satisfaction have been added proofs that the public was content, as it always is in prosperity, and that my course secured the decided approval of that enlightened faction of the people for whose approbation alone am I generally in any wise anxious.

Yours, very respectfully,

STANFORD E. CHAILLÉ,
*Supervising Inspector.*

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## APPENDIX 1.

### *Official correspondence concerning the assignment of an inspector of the National Board of Health to the Mississippi River quarantine station.*

WASHINGTON, D. C., *February* 19, 1881.

Dr. JOSEPH JONES,
*President State Board of Health of Louisiana:*

SIR: I am directed by the executive committee of the National Board of Health to address a communication to you relative to the resumption by the Board of the system of sanitary inspections at New Orleans of railroads and river craft which was put into operation last summer at the request of the State board of health of several of the Mississippi Valley States, including that of the State of Louisiana, as represented by yourself.

This Board is willing to renew these inspections for the coming season, but before assuming the responsibility involved in such action it desires to know whether it will have adequate facilities for obtaining the information necessary to enable its inspectors to furnish positive and trustworthy certificates. To this end I am instructed to inquire whether the State board of health will accede to the following propositions:

1. That an inspector of the National Board be stationed at the Mississippi quarantine for purposes of observation and inquiry, who shall have the privilege of inspecting, in company with the quarantine officer, all vessels arriving at the station, and who, in the event of a difference of opinion between himself and the quarantine officer as to the actual sanitary condition of such vessels, and to the treatment which they

require, shall send to the president of the State board a copy of his report made to the National Board.

2. That an agent of the National Board to be stationed in New Orleans shall have access to the daily reports of deaths received by the State board and of sickness when reports of sickness are made, and that whenever either the agent of this Board or the health authorities of the State receive information of the alleged existence of one or more cases of disease of a doubtful or suspicious character as to its being infectious, the State board agrees to send one of its officers, who, together with the agent of the National Board, shall investigate the case, the two parties reporting the result to their respective boards.

An early answer to these inquiries is respectfully requested.

Respectfully, yours,

J. L. CABELL,
*President National Board of Health.*

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WASHINGTON, *May* 17, 1881.

Hon. L. A. WILTZ,
*Governor of Louisiana, New Orleans:*

SIR: I am instructed by the executive committee of the National Board of Health to invite your attention to a proposition submitted on behalf of the said Board to the board of health of the State of Louisiana in a letter of February 19, a copy of which is herewith inclosed. In the published proceedings of the meeting of the State board consequent on the reception of this letter it is stated that the question relative to the placing an inspector of the National Board of Health would be referred to your excellency.* It is believed that no objection will be made on the part of the State board or of the quarantine officer, and that both are disposed to co-operate with the agent of the National Board in New Orleans in the discharge of the duties which have been assigned to him. I am also directed to say that the National Board desires to maintain at Eadsport an inspecting station with authority to prohibit the passage up the river of actually infected vessels until the same shall have undergone suitable and adequate disinfection at the Refuge at Ship Island. It is not proposed to apply these measures to any other than infected vessels, the proportion of which to the rest of the shipping is so small that there will be no serious interruption to commerce, while the chances of spreading the infection will be greatly diminished. An early reply is respectfully requested.

Very respectfully, your obedient servant,

J. L. CABELL,
*President of the National Board of Health.*

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NEW ORLEANS, *May* 26, 1881.

Hon. L. A. WILTZ,
*Governor of Louisiana:*

SIR: I respectfully ask your attention to the inclosed copy of a resolution passed by the State board of health of Louisiana at a meeting held April 19, 1881. As resident member of the National Board of Health, and in its behalf, I have the honor to inform you that the National Board deems it important to the public interests that the inspector therein referred to be assigned to duty at the quarantine station at an early date. I therefore respectfully request your assent to such assignment. An early reply is respectfully requested.

Very respectfully,

S. M. BEMISS,
*Member National Board of Health.*

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EXECUTIVE DEPARTMENT, STATE OF LOUISIANA,
*New Orleans, June* 4, 1881.

Dr. S. M. BEMISS,
*Resident Member of National Board of Health:*

DEAR SIR: I am directed by his excellency Governor Louis A. Wiltz to acknowledge his receipt of your letter of May 26, 1881, calling his attention to the resolution of the State board of health, adopted April 19, 1881, informing him that the National Board of Health deem it important to the public interests that the inspector therein referred to be assigned to duty at the quarantine station at an early day, and requesting his assent to such assignment. The governor directs me to state that the request of the National Board is complied with by him.

I have the honor to remain your obedient servant,

E. W. HALSEY,
*Private Secretary.*

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*On April 19 the State board "*Resolved,* That this board is of opinion that it is without power to nominate or appoint any Mississippi quarantine station inspector whatever, and refers the matter of such nomination and appointment to his excellency the governor."

## APPENDIX 2.

### *Reply of the Louisiana State board of health to President Cabell.*

OFFICE BOARD OF HEALTH, STATE OF LOUISIANA,
*New Orleans, March* 15, 1881.

A communication from Dr. J. L. Cabell, president of the National Board of Health, under date of February 19, 1881, having been read at the meeting of the board of health of the State of Louisiana, at its meeting held March 10, Mr. Booth offered the following remarks and resolutions, as hereunto annexed.

S. S. HERRICK, M. D.,
*Secretary Board of Health.*

In the matter of the communication from Dr. Cabell, president of the National Board of Health, this board receives it with the consideration which its source and its subject alike merit, and in the nature of an answer thereto beg to submit briefly the following views upon its polite requests and suggestions:

1. As to the resumption by the National Board of Health of the system of sanitary inspectors at New Orleans of railroad and river craft, as operated during last summer, &c., this board affirms its former position of cheerful consent thereto, and will co-operate in making these inspections as useful and as perfect as possible.

The board trusts that the several States of the Mississippi Valley will continue their adhesion and support to a work so desirable and important.

2. In the matter of facilities for obtaining information necessary to enable the inspectors of the National Board of Health to furnish positive and trustworthy certificates, this board can only repeat its assurances that every facility lawfully within its power, or accessible to its officers, shall be given. The pledge of the board, given by President Choppin, has been loyally redeemed, and continues to be the sincere determination of the present members. This board will hereafter, as heretofore, use every diligence to ascertain and communicate what is true with care and promptitude, and the National Board of Health may depend upon its agents receiving such assistance as is due them under the pledges of this board.

3. As to the proposition that there shall be an inspector of the National Board of Health stationed at the Mississippi quarantine for the purpose of observation and inquiry, who shall have the privilege of inspecting, in company with the quarantine officer, all vessels arriving at the station, and also, in the event of a difference of opinion between himself and the quarantine officer as to the actual sanitary condition of such vessels, and as to the treatment which they require, shall send to the president of the State board a copy of his report made to the National Board, it may be premised that it involves legal points which prevent this board from passing upon it without having been referred to its counsel or to the attorney-general of the State, to see by which, if any, authority this board could intervene in a matter not confided to it by law, that is, the nomination of officers at the Mississippi quarantine station.

It is presumable that if this board is without authority for the proposed step, it is unnecessary to enter upon its merits.

The board is but frank in adding that it is not in doubt as to its position and limitations under existing laws, and is of opinion that it would be idle to seem to grant what it is powerless to enforce. Still the proposition will be referred as above, and the resulting opinions or actions promptly communicated.

4. The application that an agent of the National Board of Health representing it in New Orleans shall have access to the daily reports of deaths is a public right open to and enjoyed by all who please to take advantage of it, and the press continually keeps the public advised of the daily mortuary.

5. In the matter of reported sickness not mortuary there are no formal reports provided for, but when under certain conditions cases assume phases of doubt or suspicion as to their infectious character or tendency, this board follows the wise precedents of former boards in calling consultations with experienced physicians of high rank, who, together with the president of the board and its medical members, form a committee of experts to diagnose and decide upon the status of such cases as in any manner come under review.

It is believed that no plans so far proposed can be more likely to give correct results or be intrinsically better than that already in vogue, and this board has no objection to include among its invited experts any medical gentleman, agent, or representative of the National Board of Health who may be in New Orleans at the time when the board may deem it desirable for the ascertainment of facts to call in members of the profession in aid of the president and to guide the judgment of the board.

But in all cases the board recognizes the inalienable right of the physician in attendance to judge for himself and to give his certificate to the board on that judgment, and to this end he has the undoubted right to call in consultation with him whoever of the profession he may find convenient or agreeable to himself.

Wishing to meet every well-intended overture in a spirit of fairness and candor, this board has thus passed before it all the points found in the communication of the president of the National Board of Health, and hopes that the explanations made, pledges renewed, and information given will prove satisfactory. Therefore—

1. *Resolved*, That the propositions to place an inspector or agent of the National Board of Health at the Mississippi quarantine station be referred to the counsel of the board, who is hereby requested to confer with the attorney-general of the State as to the authority of this board to appoint or place an agent or inspector of the National Board of Health at the Mississippi quarantine station as proposed.

2. *Resolved*, That the foregoing and appended resolutions and views shall be taken as the response for the present of this board, and that the president be requested to communicate the same at early convenience to Dr. Cabell, president of the National Board of Health, with such prefatory or explanatory remarks as he may see necessary or deem useful to be made.

In conclusion, the board ask to append as part of this answer two resolutions passed at their regular monthly meeting, March 10, 1881. (See reply below to the Sanitary Association.)

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OFFICE BOARD OF HEALTH, STATE OF LOUISIANA,
*New Orleans, March* 15, 1881.

At a meeting held March 10 the following propositions were presented by the president, Dr. Jones, and received general assent:

1. The headquarters of the railroad and river inspection service to be at the board of health.
2. The State board reserves the right to nominate the inspectors from active, intelligent, and upright medical men.
3. The inspectors to have daily access to the death list, and also to the cases reported to the board of health demanding investigation.
4. All reports of inspectors to be furnished in duplicate to the State and National boards.

A true copy from the minutes.

S. S. HERRICK, M. D.,
*Secretary Board of Health.*

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*Reply of the Louisiana State board of health to the New Orleans Auxiliary Sanitary Association.*

Whereas there has been laid before the board an extract from the minutes of the regular meeting of the executive committee of the New Orleans Auxiliary Sanitary Association, containing statements and resolutions adopted February 26, 1881, to the effect that "an agent or representative of the National Board of Health be seated at this board; also that an agent or inspector of the National Board of Health be stationed at the Mississippi quarantine station"; and

Whereas the latter of these propositions has already been suggested by the president of the National Board of Health, to which a response, with reasons therefor, has been made by this board, and considering that the former of these propositions, that is to say, the seating of an agent or representative of the National Board of Health at this board, involves substantially the same question, and needs to be referred to counsel for advice before the board can take action thereon; and

Whereas it is the constant desire of this board to treat the expressed wishes of their fellow-citizens with the greatest respect. Therefore—

1. *Resolved*, That the subject-matter of said resolutions be referred to the counsel of the board for report, after conference with the attorney-general of the State as to the powers of the board to act in the premises; said report of counsel, when made, to be submitted to the board at its next succeeding meeting.

2. *Resolved*, That the president be requested to address an invitation to all State boards in contiguous or neighboring States, especially those of the Mississippi Valley, to be represented near this board at any time by accredited agents, to whom shall be cheerfully accorded every facility for examination and information upon all matters affecting the public health which may in any manner come to the knowledge of this board or its medical inspectors, and to whom the records of the office shall be open for examination, transcription, or study of any statistics deemed useful or of public interest. And, further, that they or any of them, or any agents or representatives of any other health organizations or boards, local or national, or any citizens not health officials, are invited to be present as spectators and auditors at the meetings of the board, as there is transacted at such meetings only public business, in which the people have an unquestioned right to participate according to law.

## APPENDIX 3.

*Extracts from the proceedings of April 2, 1881, of the New Orleans Auxiliary Sanitary Association.*

Mr. C. A. Whitney, president of the association, took the floor and said:

I beg to inform you that just prior to our last meeting I received a long communication from Dr. Joseph Jones, president of the State board of health, in relation to the resolutions adopted by this association, respectfully asking a reconsideration of their action relative to the admission at their meetings, for purposes of information only, of a representative of the National Board and a representative at the quarantine station on the Mississippi River. As the letter has been published and you are doubtless familiar with its contents, I simply submit it for your consideration. I do not know that anything further can be done by us; but, in order that a matter so important to the welfare of this community be not utterly abandoned, and for the purpose of making known the precise position of this association with reference to this subject, I have prepared an address, which I submit for your approval.

"To his excellency Louis A. Wiltz, governor of the State; Hon. Joseph Shakspeare, mayor, and administrators; Thomas L. Airey, president of Cotton Exchange; E. K. Converse, president Produce Exchange; Cyrus Bussey, president Chamber of Commerce:

"At a meeting of the Auxiliary Sanitary Association, held on the 26th of February, the following preamble and resolutions, embodying substantially views previously expressed by the Sanitary Council of the Mississippi Valley, the Chamber of Commerce, and the New Orleans Medical and Surgical Association, were adopted, with but one dissenting vote, and were subsequently approved by the signatures of hundreds of the most prominent business and professional gentlemen of the city:

" 'Whereas the Sanitary Council of the Mississippi Valley, composed of the members of the boards of health and of the sanitary officers of the States and municipalities adjacent to and in closest relations with New Orleans, has requested the Louisiana State board of health to invite a representative of the National Board of Health to attend all the meetings of the said Louisiana State board of health, and to have free access to all its sources of information concerning the sanitary condition of New Orleans and its vicinity during the season of danger from yellow fever, and another representative to be stationed at the Mississippi River quarantine station during the same period and with similar privileges; and

" 'Whereas it is evident that only by compliance with this request that unreasonable apprehensions of danger can be anticipated, and premature and unnecessary restrictions upon commercial and personal intercourse with New Orleans be prevented; and

" 'Whereas large allowance should be made by New Orleans for the easily excited fears of those communities whose protection against yellow fever is supposed to depend to a considerable extent upon early and accurate information concerning its appearance and progress in this city and neighborhood, and that every rational concession should be made to secure their confidence and good-will:

" '*Resolved*, That the Louisiana State board of health be urgently requested to reconsider its late action in regard to this question, and to acquiesce in what has been asked by the Sanitary Council of the Mississippi Valley.'

"In addition, because of the vital importance of the subject, and the long interval of more than four weeks between the regular meetings of the State board of health, the association passed a resolution politely asking the board of health to hold a special meeting for the consideration of the question. No response whatever was made to this request; nor did the board at its subsequent regular meeting take the slightest notice of the communication, not even so much as to acknowledge its receipt. However, at this same meeting of the State board, a letter of a similar character from the president of the National Board of Health, J. L. Cabell, M. D., LL. D., of Virginia, was read, and definite action upon its contents postponed for another month by a resolution referring certain unimportant legal technicalities to the attorney of the board and the attorney-general of the State.

"On the 26th of March, at 3 p. m., just one month after the action taken by the association, and only four hours previous to its regular weekly session, a package from the Louisiana State board of health was placed upon the office-table of the president of the association. The package was not opened until 6 p. m., when it was found to contain a communication from the president of the State board of health, dated five days before, March 21, and covering thirty-three pages of extra large foolscap paper, which, with the accompanying copies of letters, amounted to forty-four closely-written pages. Owing to their great bulk, the documents could not be immediately read, and were not, therefore, transmitted to the meeting of the association, which was held an hour later. Notwithstanding this, the communication was published by its author in one of the city newspapers the following morning, and was thus spread before the public in advance of an opportunity for its consideration by the association.

"You must have observed, if you carefully read the four closely-printed columns over the signature of the president of the board of health, that the plain and reasonable requests made by the Sanitary Council of the Mississippi Valley, and the other organizations already mentioned, have been carefully evaded; the generous and catholic spirit of the board of health paraded in glowing colors, and imaginary legal difficulties made to assume insuperable proportions. For the purpose of aiding the board in the solution of these grave legal questions, we have taken the liberty to submit the same to several distinguished members of the New Orleans bar, and have the pleasure of herewith appending their replies.

"It must be evident, however, to the most careless reader that the spirit and tone of the communication of the president of the Louisiana State board of health furnish no encouragement whatever to the idea that it may yet acquiesce in the simple and equitable demands which have been made upon it, notwithstanding the effort made to convince the public that the main points were granted long before they were raised. And what are these demands? At the risk of being a little tedious, we venture to state them again by quoting from the letter of Dr. Cabell, of the National Board of Health, which letter only repeats the requests made by the sanitary authorities of the State in closest relation with New Orleans:

"'1. That an inspector of the National Board be stationed at the Mississippi quarantine station for purposes of observation and inquiry, who shall have the privilege of inspecting, in company with the quarantine officer, all vessels arriving at the station, and who, in the event of a difference of opinion between himself and the quarantine officer as to the actual sanitary condition of such vessels and as to the treatment which they require, shall send to the president of the State board a copy of his report made to the National Board.

"'2. That an agent of the National Board, to be stationed in New Orleans, shall have access to the daily reports received by the State board, and of sickness when reports of sickness are made; and that whenever the agent of this board or the health authorities of the State receive information of the alleged existence of one or more cases of disease of a doubtful or suspicious character as to its being infectious, the State board agrees to send one of its officers, who, together with the agent of the National Board, shall investigate the case, the two parties reporting to their respective boards.'

"What can be more just or equitable to the numerous States of the valley of the Mississippi, which are by geographical position and commercial relations as deeply interested in the sanitary regulations of the outlets of the great river as the citizens of New Orleans themselves? No demand is made for any participation in the powers or authority of the State board; no discreditable reflection is made upon the dignity of this body, no slight is put upon a single one of its members. All that is asked is that the National Board of Health be granted equal opportunities for obtaining prompt and accurate information concerning sickness or suspected sickness of an infectious nature which may occur in or near New Orleans or upon the vessels which enter her waters and threaten to extend to neighboring States. We have no evidence that this has been acceded to, and the object of this address is to urge you to consider the serious results which are likely to follow. On the 20th of April the Sanitary Council of the Mississippi Valley, which, although a 'voluntary association,' is nevertheless an association of sanitary authorities, and thereby wields an immense power over the sanitary regulations of the States adjacent to the Mississippi River and its tributaries, will hold its annual session at Evansville, Ind. We are positively assured that at this meeting, unless the Louisiana State board of health shall in the mean time revise its former action, and grant without reservation the reasonable request which has been made, measures of self-protection will be recommended to the respective States, and New Orleans will in all probability be isolated during the whole ensuing summer by a most effective system of interior quarantine.

"We have no new suggestions to make as to how this impending calamity may be averted, but whatever is to be done should be done quickly. We, as an association, have performed our duty in the premises to the best of our knowledge and ability, and can now only make this our earnest appeal to your superior authority, and leave the matter entirely in your hands."

The following are the interrogatories propounded to Messrs. J. A. Campbell, R. H. Marr, H. C. Miller, W. W. Howe. E. D. White, J. B. Eustis, and Henry J. Leevy, attorney for the New Orleans Auxiliary Sanitary Association:

"1. Would the Louisiana State board of health violate any laws or exceed its authority by permitting a representative of the National Board of Health to be present at all its sessions from the month of May to that of November, inclusive, to pledge itself and each of its members to give said representative immediate and full information concerning any suspected cases of yellow fever which may occur in or adjacent to the city during the period mentioned, and grant him equal opportunity for examining such cases?

"2. Would the Louisiana State board of health violate any laws or exceed its authority by permitting a representative of the National Board of Health to reside, at the expense of the latter, from May to November, upon the grounds of the Mississippi River quarantine station, and by granting him equal facilities with those possessed by the quarantine physician for obtaining prompt and accurate information concerning the arrival and presence of all vessels and persons infected or suspected of infection by yellow fever?"

I know of no law which the Louisiana State board of health would violate, nor do I know in what respect the board would exceed its authority by permitting a representative of the National Board of Health to be present at all its sessions from the month of May to that of November, inclusive; to pledge itself and each of its members to give said representative immediate and full information concerning any suspected cases of yellow fever which may occur in or adjacent to the city during the period mentioned; and grant him equal opportunity for examining such cases.

I may add that there is a wide difference between that which the board may have *lawful* power and authority to do, and that which it is compelled by law to do; and that it might be necessary for the board to have occasional sessions, merely for the purpose of its general business and administration, at which the presence of any others than members of the board would be neither useful nor desirable.

To the second interrogatory I answer that I know of no law which the Louisiana State board of health would violate, nor do I know in what respect it would exceed its authority "by permitting a representative of the National Board of Health to reside, at the expense of the latter, from May to November, upon the grounds of the Mississippi River quarantine station, and by granting him equal facilities with those possessed by the quarantine physician for obtaining prompt and accurate information concerning the arrival and presence of all vessels and persons infected or suspected of infection by yellow fever."

R. H. MARR.

In answer to the two questions submitted by you, and upon which you request my opinion, I have the honor to state that the Louisiana State board of health would not violate any law by permitting a member of the National Board of Health to be present at the sessions of the State board, or to reside at the quarantine station, for the purposes and under the conditions indicated in your questions.

J. B. EUSTIS.

I see nothing in the laws creating the board or governing quarantine which would render it illegal or impossible to grant the requests covered by the interrogatories stated.

E. D. WHITE.

The board of health is a body corporate, having an important function to perform for the State and clothed with powers of administration adequate to the performance of their public duties. Among these faculties are those for the management of their own affairs, and to prescribe rules for their own government.

Your first interrogatory is whether they are competent to authorize a representative of the National Board of Health to attend the sessions of their board; and to agree to communicate freely and unreservedly to that representative information which they may have relative to any suspected case of yellow fever which may occur within their jurisdiction, between the first day of May and the first day of November of each year, and to allow that representative to inspect or examine such cases. We understand the National Board of Health to have been established to perform in the neighborhood, functions analogous to those of the board of health of the State.

Both corporations are organized for a common purpose of promoting the general utility and protecting the health of the community.

We cannot discern any cause for excluding either board from any opportunity for obtaining exact and immediate information of all that is important for them to know.

That there has been no restriction upon the board of health of this State, and upon their authority to confer all that is contemplated in your question upon the representative of the National Board of Health, in our opinion, is indisputable.

Second. The board of health is established for the purpose of maintaining a quarantine system as essential to the security of the State.

The members of the board must be zealous in its support to fulfill their obligation.

The board may employ nurses and assistants for the sick and other persons required to carry out quarantine duties, and to make all needful rules and regulations for the maintenance of quarantine, and the board may establish quarantine stations and make all needful rules and regulations with respect to them.

Your second question is whether any law would be violated by the permitting of a representative of the National Board of Health to reside upon the grounds of the Mississippi quarantine station, and granting to him all the facilities allowed to the resident physician for obtaining prompt and accurate information concerning the arrival and presence of all vessels and persons infected or suspected of infection by yellow fever.

We answer that they have full power to grant such permission at their discretion. We have examined the rules and regulations of the board of health, and find in the sections enumerating their powers (page 37) ample authority to them to do all which is contemplated to be done under either of your questions.

J. A. CAMPBELL.
W. W. HOWE.
HENRY C. MILLER.

I have carefully examined the statutes relating to the powers of the State board of health, and fully concur in the above.

HENRY J. LEOVY,
*Attorney for Auxiliary Sanitary Association.*

Mr. Lyman said that as the representative of the sanitary association he had attended the meeting of the Sanitary Council of the Mississippi Valley, and he was struck with the manifest distrust with which the Louisiana State board of health was regarded, and the evident desire of the council to have a National Board of Health officer admitted to the meetings of the State board.

While in Saint Louis, a short time ago, he had been told by the president of the Illinois board of health, whom he happened to meet there, that unless a National Board of Health officer was put in position to obtain early and accurate information from the Louisiana State board of health, New Orleans was liable to be isolated.

He offered the following resolutions relative to the matter, which were adopted:

*Resolved*, That we approve and indorse the address prepared by the president of this association in relation to our recommendation to the State board of health to admit at their meetings, for purposes of information only, a representative of the National Board of Health. and for the same purpose a representative at the quarantine stations on the Mississippi River, and that we accept as our own the statements and views therein expressed.

*Resolved further*, That the secretary be instructed to send copies of the address to his excellency the governor of the State, his honor the mayor of the city, and to the president of the board of health, the Cotton Exchange, the Chamber of Commerce, and the Produce Exchange.

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## APPENDIX 4.

### *General instructions of the National Board of Health to the supervising inspector at New Orleans.*

NATIONAL BOARD OF HEALTH,
*Washington, D. C., April 28*, 1881.

Dr. S. E. CHAILLÉ,
*Supervising Inspector, National Board of Health, New Orleans, La.:*

SIR: I am directed by the executive committee of the National Board of Health to forward the following instructions for your guidance during the coming summer. The objects which the National Board of Health desire to secure through you are: First, to obtain the earliest possible information of the existence of yellow fever in New Orleans or its vicinity; second, to secure free commercial intercourse between New Orleans and other points so long as such intercourse is unattended with danger; third, when by reason of the existence of yellow fever in Louisiana, intercourse must be carried on with other States under certain restrictions to so arrange matters that these restrictions shall cause no more interference with commerce than is absolutely necessary; and fourth, in case of the appearance of yellow fever in New Orleans to co-operate in every way to limit the spread of the disease and to stamp it out if possible.

I inclose herewith for your information copies of certain municipal and State ordinances recently enacted (A), from which you will see that it is only upon your certificates, or upon the certificate of inspectors duly authorized by you, that boats from New Orleans will be allowed to land at the places in question during the coming summer. Your duties, therefore, have great importance, and involve a heavy responsibility, both in preventing danger to surrounding communities on the one hand and to prevent unnecessary interference with the commerce of New Orleans on the other.

The possibility of your being able to obtain the second object, by giving the certificates required by the above-mentioned and similar ordinances, will depend to a great extent upon the possibility of your obtaining from the health authorities and physicians of New Orleans, and of the river parishes below New Orleans, such co-operation and information as will justify you in taking the responsibility of certifying on behalf of the National Board of Health that New Orleans is free from yellow fever, or that if this disease is present it is so located and of such a character that the city is not "dangerously infected" thereby. In making or authorizing to be made in behalf of the National Board of Health statements that New Orleans and its vicinity are free from yellow fever, you will consider yourself justified in so doing only so long as you are satisfied that you are in receipt of prompt and reliable information as to the condition of affairs at the Mississippi River quarantine station and its vicinity, and also as to the health of the city itself, as shown by the certificates of death and the absence of reports of doubtful or suspicious cases. The National Board of Health has received a communication from the Louisiana State board of health offering to the inspector of this board a commodious room adjacent to and communicating with the rooms and offices of the State board at the State capitol, and also requesting said inspector to be present as auditor and spectator at the meetings of the State board. A copy of this resolution (B) and of the reply thereto (C) is inclosed for your information. In order that you may obtain the information above referred to, two things seem to be essential. The first is that you shall receive regular daily reports from an inspector of this board, to be placed at the Mississippi River quarantine station, whose duty it shall be to accompany the quarantine officer in his inspections of all vessels arriving at the station, and who shall in the event of any difference of opinion between himself and the quarantine officer as to the actual sanitary condition of such vessels, and as to the treatment which it requires, forward at once to you a report upon the case, furnishing at the same time a copy of this report to the president of the Louisiana State board of health.

Second. That all reports of deaths and the original returns made by the attending physician of doubtful and suspicious cases made to the Louisiana State board or to any member thereof, shall be communicated to you at once, whether they may have been formally presented to a meeting of the State board and entered on its files or not, and that if any of these cases shall appear to you to be of a sufficiently doubtful or suspicious character to demand it you will upon notifying the proper officer of the State board be permitted to investigate the case in connection with such person or persons as may be appointed to accompany you by the State board.

You will co-operate with and endeavor to secure the co-operation of the Louisiana State board and the other sanitary and medical organizations of the city in securing information as to the presence of cases of yellow fever or of doubtful or suspicious cases of this disease. In doubtful cases, where difference of opinion may arise as to the character of the disease, you will be guided by the rules for this purpose which have been drawn up and approved by the Medical and Surgical Association of New Orleans, a copy of which is herewith appended, marked D. Should a case of yellow fever, or a case which appears to you doubtful or suspicious, occur either in New Orleans or vicinity, you will not announce it, except to the resident member of the board, the president of the State board of health, the superintendent of river inspection, and the secretary of the National Board of Health, and will leave to the secretary of the National Board of Health the responsibility of announcing it; but in case you are called on for information in this regard by the health authorities of other States and municipalities you will furnish such information to the best of your ability, subject, however, to the approval of the resident member of the National Board of Health. You will furnish the information above directed as to the presence of cases of yellow fever whether you are able to secure the co-operation of the local board or not, and you will understand that this applies to suspicious cases as well as to cases the nature of which is clearly established by diagnosis to be yellow fever. It must be constantly borne in mind that the occurrence of a case or even of two or three cases, of yellow fever in the city of New Orleans is not in itself a sufficient cause for cessation of commercial intercourse with that place or to cause it to be proper to declare New Orleans to be a "dangerously-infected" city; and while it is proposed to keep the health authorities of surrounding States and cities as promptly and fully informed as possible as to the actual sanitary condition of New Orleans as regards the existence of yellow fever there, the National Board desires to use its best influence to prevent any undue restrictions upon the travel or traffic from that city until it becomes evident that danger would result from their continuance. The action to be taken by the National Board of Health in the event of the occurrence of a case of yellow fever in New Orleans must depend greatly upon the precise point in the city where such case appears, its relations to the commercial portions of the city, its tendency to spread, &c. You will be careful to keep this office fully advised, and, when necessary, by telegraph, of all these facts with relation to the earlier cases, and also as to what steps are being taken to secure isolation, systematic disinfection, &c. In case yellow fever appears in the city of New Orleans during the summer, it is the desire of the National Board to co-operate in every way with the health authorities of the city to restrict the spread of the disease and to stamp it out if possible, and to this end it will be prepared to pay for such services and materials as are necessary for this purpose. It will, therefore, become your duty, as its representative and chief executive agent in New Orleans, to decide what measures are necessary and proper for the purpose indicated, and to see that they are applied as promptly and as energetically as possible.

Detailed instruction as to method of procuring funds and supervising of accounts to be incurred, &c., will be furnished from this office.

You will please make arrangements to commence a system of inspection of steamboats bound up the river upon the 1st of May, the methods of inspection and the general form of certificates to be given being those employed in the inspection of last year, subject to such changes as may be approved hereafter; for this purpose you are authorized to employ, subject to the approval of the executive committee, two inspectors at a rate of compensation not to exceed $150 per month, which shall include all allowances and expenses, and in case you deem them necessary, two sanitary policemen at a compensation not to exceed $50 per month.

It does not at present seem necessary to undertake any system of complete railroad inspections, the only precaution in this direction which is desirable being the examination of freights as was done last year.

You will please furnish at once the names of gentlemen whom you would recommend as suitable for inspectors of steamboats, &c., and also for the position of inspector at Mississippi quarantine station. In making these selections, please bear in mind that the gentlemen who are to perform these duties, if they are to succeed, must have tact as well as knowledge, firmness, and unquestionable honesty. They will have no authority whatever to interfere in any way except by giving their advice.

It is considered highly desirable by the National Board of Health that infected ships should be as far as possible excluded from the Mississippi River, and that you will endeavor to secure the co-operation of the Louisiana State board of health toward obtaining this result, by having said board pass an ordinance similar to "resolution 6," passed by the Sanitary Council of the Mississippi Valley at its late meeting, to the effect that all vessels from ports in which yellow fever is prevailing, or from ports where contagious or infectious diseases are reported to exist shall be inspected at Eadsport, and if any such be found to be infected, or to furnish reasonable ground for suspicion of infection, such vessel shall not be allowed to pass Eadsport northwise, except upon presentation of a certificate from the inspector of the National Board of Health at the Ship Island quarantine station, setting forth that the vessel has been subjected to proper treatment and is free from liability of conveying contagion. You will furnish to this office a weekly report of the ordinary operations of your department, inclosing in it the reports of your subordinates, and, in case of an emergency, you will keep this office fully advised of the situation, using the telegraph freely, if necessary, for this purpose.

Finally, it is especially desired that you will keep Dr. S. M. Bemiss, resident member of the board in New Orleans, fully advised at all times of the information which you may receive and the operations of your office. You will submit to him all reports which you may make, obtaining his opinion thereon, and counsel freely and fully with him with regard to all your operations. While the board will hold you, and not Dr. Bemiss, responsible for the management of its business in New Orleans during the coming summer, and does not desire to occupy his time with its work, unless under exceptional circumstances, it desires, nevertheless, to have the benefit of his knowledge and counsel in all matters pertaining to sanitary work in New Orleans or its vicinity.

I am, doctor, very respectfully, &c.,

T. J. TURNER,
*Secretary National Board of Health.*

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*Documents referred to in the foregoing letter of instructions.*

A.

OFFICE OF THE BOARD OF HEALTH,
*Memphis, March 29, 1881.*

T. J. TURNER, M. D.,
*Secretary National Board of Health, Washington, D. C.:*

SIR: I have the honor to forward you the accompanying attested quarantine ordinance of the legislative council of the taxing district of Shelby County (the city of Memphis) and the resolutions of this board of health relating thereto, adopted this day. In support of these resolutions I respectfully urge the paramount necessity of timely preparation in order that, before the advent of warm weather and its attendant dangers, the inspection service and other precautionary measures may be thoroughly understood and in satisfactory operation. I cannot help regarding the coming summer season as a critical one for the experiments of protecting the public health of the Mississippi Valley by a system of sanitary inspection and surveillance. Upon its success during the current year in a great measure depends the stability and progress of preventive medicine in this region. If it is reasonably successful under the circumstances of fair tests, which there are just grounds to apprehend will arise, its continuance and future development may be considered assured.

But, should it fail, no matter from what cause, the valley communities, per force of public opinion, will resume the old system of non-intercourse local quarantines, with their manifold drawbacks, costly and vexatious interruptions to commerce and travel.

At least one unavoidable cause of failure, namely, inadequate preparation and undue postponement, should not be imputed to us, and it is to be hoped the National Board will extend the co-operation and aid asked for promptly, and, as far as practicable, effectively.

It is respectfully submitted, in view of recent developments, that inspections should be begun in New Orleans as much earlier than May 1 as practicable.

I am, sir, respectfully, your obedient servant,

G. B. THORNTON, M. D.,
*President Board of Health.*

## QUARANTINE ORDINANCE.

First. Be it ordained by the legislative council, That on and after May 1 no steamboat, barge, tug, tugboat, or other water-craft coming from any point south of the port of Memphis shall be allowed to enter or land at this port without having a clean bill of health or inspection certificate, issued or countersigned by an inspecting officer of the National Board of Health stationed at quarantine on President's Island, showing that such water-craft, its outfit, furniture, &c., and its passengers and crew are in such condition of health and freedom from contagious and infectious diseases as to make it safe for such craft to enter and land at this port.

Second. Be it further ordained, That any captain, owner, employé, or other persons or officers in charge of such boat, barge, or other water-craft, who shall violate this ordinance shall be arrested, and upon conviction before the president of the board of fire and police commissioners, be fined not less than $1 nor more than $50 for each and every offense, and such boat or other water-craft shall at once, upon landing or entering in violation of this ordinance, be removed beyond the limits of the port.

Passed May 27, 1880.

D. T. PORTER, *President.*

Attest: C. L. PULLEN, *Secretary.*

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OFFICE BOARD OF HEALTH,
*Taxing District, Shelby County, Tenn., March* 29, 1881.

Dr. T. J. TURNER, U. S. N.,
*Secretary National Board of Health, Washington, D. C.:*

DEAR SIR: At a meeting of the board of health held to-day the following resolutions were passed:

*Resolved*, That the National Board of Health be respectfully requested to place on duty at New Orleans, and such other Southern ports as may be deemed necessary, an inspector or inspectors, whose duty it shall be to supervise the shipment by river or rail of any goods, merchandise, baggage, &c., and to advise (by cipher telegram) the resident member of the National Board of Health in this city, or in the event of his absence, his official representative, whenever such shipments are believed to be infected or in any wise dangerous to the public health, and that the National Board instruct its resident member to promptly notify this board of the shipment of such such infected or dangerous goods, &c., for this city.

*Resolved*, That the quarantine grounds and buildings on President's Island be again tendered to the National Board of Health for use as an inspection station for the enforcement of quarantine ordinance of the taxing district, which takes effect May 1, proximo, and for the general purposes of the inspection service of the National Board of Health.

*Resolved*, That copies of these resolutions and of the quarantine ordinance be transmitted to the Secretary of the National Board of Health at Washington.

R. B. KING, M. D.,
*Secretary Board of Health.*

VICKSBURG, MISS., *February* 12, 1881.

To the SECRETARY NATIONAL BOARD OF HEALTH,
*Washington, D. C.:*

DEAR SIR: At a regular meeting of the board of mayor and aldermen, held on the evening of February 7, the following resolution was adopted, to wit:

*Resolved*, That the National Board of Health is hereby earnestly requested to put in operation the inspection of steamboats and other water-craft between this city and the city of New Orleans by the fifteenth day of May next, and that a copy of the above ordinance and resolutions be forwarded to the National Board of Health at Washington, D. C., for their action.

Hoping to hear from your body at an early day, I am, most respectfully, &c.,

T. G. BIRCHETT,
*Mayor.*

Inclosed find ordinance—

Whereas the presence of yellow fever at Vera Cruz, Mexico; Rio de Janeiro, Brazil; Havana, Cuba; island of St. Thomas, and other tropical ports, renders it liable by importation to our principal seaport, New Orleans: Therefore,

Be it ordained by the mayor and aldermen of the city of Vicksburg, Miss., That from and after the fifteenth day of May next, no steamboat or other water-craft coming from below will be permitted to land at Vicksburg, discharge freight, or put off passengers, unless said craft shall have a certificate from a sanitary inspector of the National Board of Health that she has complied with the inspection rules and regulations of said board.

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## B.

NEW ORLEANS, LA., *April* 16, 1881.

*Extract from minutes of meeting held April* 14, 1881.

By Mr. Edward Booth:

*Resolved*, That this board concurs in the opinion of the State boards of some of the river States, that the National Board would do well to commence its river and rail inspections on or about the first of May, and that this board cordially indorses the invitation already extended by its president to such inspector or inspectors as may be commissioned by the National Board of Health to occupy the commodious room adjacent to and communicating with the rooms and offices of this board at the State capitol, and that the inspector or inspectors aforesaid are requested and urged to be present as auditors and spectators at the meetings of this board, with a view to give efficiency to the wishes of the National Board of Health, expressed through its president, Dr. Cabell, under date of February 19, that it may have adequate facilities for obtaining information necessary to enable its inspectors to furnish positive and trustworthy certificates.

The resolution was adopted by the following vote:

Yeas—Messrs. Hernandez, Marks, Formento, and Booth.

Nays—Messrs. Loeber, Brewster, and Beard.

A true copy.

S. S. HERRICK, M. D.,
*Secretary Board of Health.*

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## C.

NATIONAL BOARD OF HEALTH,
*Washington, April* 26, 1881.

Dr. JOSEPH JONES,
*President of the State Board of Health of Louisiana:*

SIR: I am directed by the executive committee of the National Board of Health to acknowledge the receipt of your communication of the 15th instant, transmitting extracts from the minutes of the board of health of Louisiana of April 14, 1881, and to inform you that Dr. S. E. Chaillé, of New Orleans, has been appointed supervising inspector of the National Board of Health for the coming season. I am further instructed to say that in accordance with the recommendations of your board, and those of other State boards of the Mississippi Valley, the river inspections will commence on or about the 1st of May. On behalf of the executive committee I return its thanks for the offer of a commodious room to be occupied by the agent of the National Board, in the same building with and adjacent to the rooms of the State board. The invitation to be present at the meetings of the State board will be communicated to Dr. Chaillé, who will be instructed to use his own discretion in the matter.

Very respectfully, yours,

J. L. CABELL,
*President National Board of Health.*

## D.

[The following document has been approved, so far as the diagnosis of yellow fever is concerned, not only by the New Orleans Medical and Surgical Association, but also by the Orleans Parish Medical Society and by the Louisiana State Medical Society.]

For sanitary purposes the following groups of symptoms shall be considered to indicate yellow fever:

*Group first.*—A person after (*a*) a sudden attack has (*b*) a fever of one paroxysm, attended with (*c*) marked congestion or blood stasis of capillaries of the surface, conjunctivæ, and gums, with (*d*) a history of probable exposure to infection and (*e*) no history of a previous attack of yellow fever.

*Group second.*—A person after (*a*) a sudden attack has (*b*) a fever of one paroxysm, followed by (*c*) unusual prostration, (*d*) albuminous urine, (*e*) yellowness of conjunctivæ or skin, and having (*h*) no positively authenticated history of previous attack of yellow fever.

*Group third.*—A person has (*a*) a fever of one paroxysm, (*b*) albuminous urine, (*c*) black vomit, (*d*) suppression of urine, or (*e*) general hemorrhagic tendency, under (*h*) circumstances where exposure to infection is a possibility.

1. *Suspicious cases of yellow fever.*—For sanitary purposes the following symptoms associated with a fever of one paroxysm, in a patient who has apparently been exposed to infection and has never had yellow fever, shall be held to justify (if occurring between May 1 and November 1) in either of the six following cases a suspicion of this disease, viz:

First. Suddenness of attack, either with violent pain in back and head, injected eyes and face, or with marked congestion of the superficial capillaries.

Second. Want of that correlation between pulse and temperature usual to other forms of fever.

Third. Albuminous urine.

Fourth. Black vomit.

Fifth. General hemorrhagic tendency.

Sixth. Yellowness of skin.

The following cases shall also be deemed suspicious:

Seventh. Any cases respecting which reputable and experienced physicians disagree as to whether the disease is or is not yellow fever.

Eighth. Any case respecting which efforts are made to conceal its existence, full history, and true nature, in violation of section 28, city ordinances of May 18, 1870, and section 22, city ordinances, June 24, 1879.

In the event of the death of a suspicious case a post-mortem examination should be made when practicable. Both before and after death yellow fever is specially and pre-eminently characterized by the fact that it is par excellence a hemorrhagic fever, marked by capillary congestion and its sequela; hence post-mortem evidences of a general hemorrhagic tendency in internal organs, especially in the digestive in preference to the urinary tract, shall be held to confirm the suspicion.

## APPENDIX 5.

The following report of Dr. F. Formento was unanimously adopted on May 19, 1881, by the Louisiana State board as its reply to the propositions contained in the general instructions of April 28 of the National Board of Health, which propositions were submitted to the State board on May 13:

I have carefully examined and studied the communication made to this board at its last meeting, May 13, 1881, by Dr. Chaillé, supervising inspector of the National Board of Health, and I have given to the important subject laid before us all the consideration and attention it deserves.

This communication is of great interest. The propositions which it embodies are so varied in their character and purpose, the measures submitted for our approval and consent are so momentous, that body from which these proposals emanate is entitled to so much respect, that we deem it our duty to examine them seriatim, and at what will perhaps be considered too great a length.

*Proposition No.* 1 reads as follows: "That all reports of deaths and the original returns made by the attending physicians of doubtful or suspicious cases of yellow fever to the Louisiana State board of health, or to any member thereof, shall be communicated to you (the supervising inspector) at once, whether they have been formally presented to a meeting of the State board and entered on its files or not, and that if any of these cases shall appear to you (the supervising inspector) to be of a sufficiently doubtful or suspicious character to demand it, you (supervising inspector) will, upon notifying the proper officer of the State board, be permitted to investigate the case, in connection with such person or persons as may be appointed to accompany you by the State board."

The proposition, which is almost a literal reproduction of a resolution approved April 19, 1881, by the Louisiana State board of health, is unhesitatingly accepted.

*Proposition No.* 2.—"That the State board will consent to a modification of the resolution lately adopted by it relative to investigation of cases so as to provide that, unless the report be ultimately unanimous, a majority or minority report shall be made to both boards, this being the course suggested by the National Board of Health."

With due respect for the suggestions of the National Board, the Louisiana State board still adheres to its opinion, embodied in the resolution already adopted by it, that there should be only one report sent to both the National and State boards, viz, the report of the majority of the investigating committee. By the resolution to which we refer, the State board has constituted that investigating committee in a manner calculated to give the greatest security to both boards and to the public at large as to the correctness of the decision at which they may arrive. One of them is to be selected by the National Board of Health, the other by the State board; in case of disagreement, these two are to select an umpire of their own choice, having all the necessary qualifications as to competency and character. A decision arrived at by a majority of a tribunal so composed presents all the guarantees in point of certainty and correctness which may be expected in all human affairs, and we think that it would be improper and dangerous to impair the authority of such a decision by suffering a counter-report to influence the public mind, and create perhaps a general panic. All measures adopted by either board, based upon such a majority report, will be more favorably received by the community and will inspire general confidence; the enforcement of such measures will be rendered thereby easier, and will be more willingly submitted to. In most cases the boards would be without elements necessary to enable them to decide between two conflicting reports. By the adoption of one report the duties of both the National and State boards of health will be greatly facilitated; all hesitation or controversy will be avoided in time when delay may be fatal; measures of sanitation recommended will acquire greater weight and will be productive of more beneficial results. These are the reasons which induced our State board of health to adopt the one-report plan, and for the same reasons, it feels compelled to refuse their assent to the second proposition.

*Proposition No.* 3.—"That in view of the great importance of securing the reports of the earliest cases of yellow fever, and the special stress laid upon this point in his (the supervising inspector's) instructions, which, either through ignorance or negligence of those upon whom the State board is forced to depend, might not otherwise be reported, the board (Louisiana State) be requested to approve of his (the supervising inspector's) issuing an appeal to our physicians, medical and sanitary organizations, &c., to furnish him with such information as they may have. He (the supervising inspector) pledges himself, on condition of the approval, to report any information so secured as may be of value to the State board."

It seems to us that such an appeal on the part of the supervising inspector of the National Board is superfluous. Our rules and regulations make it compulsory on the part of every practitioner of medicine, surgeon, druggist, master of any water-craft, boarding or lodging house keeper, principals or masters of any boarding-school, or seminary, &c., to report, within twenty-four hours after the same may come under their treatment, cognizance, or supervision, all cases of contagious, infectious, epidemological diseases, especially cholera, *yellow fever*, small-pox, diphtheria, trichiniasis, typhus, or ship fever, or any of the grades of such diseases. The neglect to report all such cases renders the delinquent liable to a fine of twenty-five dollars for each and every offense, and in default of payment thereof to an imprisonment not to exceed thirty days. (See article 452 of an ordinance relating to contagious and infectious diseases, No. 4916, administration series.) It is the firm intention of this board strictly to enforce the law on this subject.

The persons upon whom the State board chiefly depend (and in its opinion justly rely) for any information are its experienced, competent, and sworn officers and the whole body of the licensed practitioners of the city of New Orleans. The ignorance or negligence which seems to be apprehended by the National Board of Health does not very certainly refer to them. Outside of physicians the appeal sought for would have to be addressed to the very same parties upon whom the State board depends in a manner for information, and we do not see, if the danger of ignorance or negligence on their part exists in their relations with the State board, how the same danger will not exist in their relations with the National Board. With this remark we can see no objection towards granting to the supervising inspector the privilege of issuing his appeal, it being well understood that the information which may be given to him will not relieve the parties concerned from the duties imposed upon them of making their reports, as heretofore, to the Louisiana State board, the only authority constituted by law to receive their official communications.

The fourth proposition reads as follows: "In the case of yellow fever appearing in the city during the summer, it is the desire of the National Board to co-operate in every way with the local authorities of the city to restrict the spread of the disease and to stamp it out if possible, and to this end it will be prepared to pay for such services and materials as are necessary for this purpose. It will, therefore, become your duty (that of the supervising inspector), as its representative and chief executive agent in New Orleans, to decide what measures are necessary and proper for the purpose indicated, and to see that they are applied as promptly and energetically as possible."

In relation to this proposition we can but heartily approve and congratulate ourselves upon the so-expressed desire of the National Board to co-operate with us in all measures intended to stamp out yellow fever, if possible. We should have, however, desired that the benevolent efforts of the National Board should not have been limited to the contemplated emergency of an epidemic already existing, but should have been extended to measures calculated to prevent its outbreak, thus applying the maxim so appropriately quoted by the honorable representative of the National Board, "In time of peace prepare for war."

We now come to the fifth and most important proposition or request made by the National Board to the State board of health, viz: "It is considered highly desirable by the National Board that infected ships should be, as far as possible, excluded from the Mississippi River, and the inspector will endeavor to secure the co-operation of the Louisiana board toward obtaining this result, by having said board pass an ordinance similar to the resolution passed by the sanitary council of the Mississippi Valley at its last meeting, to the effect that all vessels from ports in which yellow fever is prevailing, or from ports where contagious or infectious diseases are reported to exist, shall be inspected at Port Eads, and if any such be found to be infected, or to furnish reasonable ground for suspicion of infection, such vessel shall not be allowed to pass Eadsport northwise, except upon presentation of a certificate from the inspector of the National Board of Health at the Ship Island quarantine station, setting forth that the vessel has been subjected to proper treatment and is not liable to convey contagion."

With all deference and respect for the National Board, and in spite of our most earnest desire to establish friendly relations and promote our cordial co-operation in order to accomplish our most cherished object, our ambition to protect our city and State, as well as the States of the Mississippi Valley, from the introduction of foreign pestilence, of yellow fever more particularly, we must acknowledge that this proposition is a cause of surprise and regret to us, for it is entirely inadmissible and impossible that we could for a moment consent to it.

Ship Island is a sand bank situated on the coast of the State of Mississippi, 100 miles from the mouth of the Mississippi River, entirely out of the course of any vessels coming to this port from any of the ports most likely to be infected, such as Rio Janeiro, Havana, and Vera Cruz. Admitting that Ship Island was the safest and the best equipped quarantine establishment in the world, that the said island presented all the sanitary advantages, with all imaginable facilities for loading and unloading vessels, for provisions, &c.; admitting that it was surrounded by deep water, permitting ships of heavy draught to load at the piers or wharves of said establishment; admitting all this, and everybody knows that the actual facts are quite the reverse, we say that this State board of health has no power conferred upon it by any of the several acts of the legislature creating said board and establishing quarantine for the protection of the State of Louisiana to order vessels out of the waters of Louisiana to any foreign or domestic port, or to any quarantine station under the jurisdiction of the United States or any State of the Union. To assume such power would simply be an abuse of authority on the part of the State board, which would not be tolerated by our State authorities nor any foreign power. Admitting that we should have the power to prevent admission in the Mississippi River of a vessel of a friendly power, doing legitimate business with our port, we have no right to force her out of her way; to be submitted to a thousand vexatious annoyances and trouble; to oblige her to procure a certificate from the inspector of the National Board of Health at the Ship Island quarantine station.

The distance from Ship Island to the mouth of the Mississippi River is 100 miles; a sailing ship during bad weather and unfavorable wind might be several days on the way.

Supposing that a vessel, after obtaining this certificate, which is to open to her the gates of the Mississippi River, should have cases of yellow fever, or other infectious diseases, to declare themselves on board of her on her way back from Ship Island station to Eadsport, an occurrence likely to take place under this latitude during the months of August and September, what then should be done with such a vessel? Should she be sent back a second time to the national station to undergo a second quarantine?

The proper place, the only one we recognize for vessels from foreign ports bound for New Orleans, to be stopped, inspected, and submitted to quarantine, established by the laws of the State of Louisiana, is our State Mississippi River quarantine station. It is admirably situated for that purpose, at a sufficient distance from our city to protect us from the neighborhood of infected ships, and yet near enough to procure provisions, supplies, acclimated laborers, physicians, nurses, &c., in case of necessity. It offers a safe and deep anchorage to immense fleets. This establishment has, under the administration of the present board of health, been put in thorough repair at a cost of nearly $7,000. It represents a value of $60,000, with large warehouses for storing cargoes; also, facilities for loading or unloading at the wharf. It has telegraph communications will all parts of the world. It is the best equipped and organized quarantine station outside of New York.

The rules and regulations governing our quarantine station are sufficiently strict to procure complete protection from foreign pestilence with as little detention and obstruction to commerce as possible.

Should we accept the proposition to inspect vessels at Eadsport and not allow them to pass northwise, except upon the presentation of a certificate of the inspector of the National Board of Health at Ship Island; in other words, should we force (if we had such power) the Ship Island quarantine upon foreign or domestic commerce, we should at once, to be consistent, abolish our State board with its well-equipped and costly quarantine establishments in the Mississippi River; we should at once abandon the power and authority conferred upon us by law; we should abandon the fulfillment of our sworn and sacred duties, that of protecting ourselves, the lives of our people, the interests of our commerce, not confiding to others, however great and powerful they may be, that sacred obligation.

Commerce once destroyed, as it would surely be by the enforcement of this strange and unnatural quarantine which is sought to be imposed upon us, we might as well abandon all our rights, powers, and duties, for Louisiana would no longer need any protection. It would be entirely ruined, and would soon disappear from the family of States. For all these reasons, and many others which we could add to these, we respectfully refuse to indorse the fifth and last proposition submitted to us by the supervising inspector of the National Board of Health.

In considering the above-mentioned proposition emanating from the National Board of Health, we have acted fairly, honestly, good intentionally, as we have done on all occasions in which points of dissension have arisen between the National Board of Health and the Louisiana State board. We consider it our duty, we deem it is due to both ourselves and our fellow-brothers of the National Board, to give fully and explicitly our honest opinions and convictions on subjects of such vital importance as those that relate to the public health.

We hereby reiterate our most earnest desire to extend our friendly relations with all sanitary organizations—with the National Board of Health more particularly. The object we are striving for is the same; public health is our aim and ambition. Each organization, in its own sphere of action, has its share of usefulness, and contributes to the public good. From the combined yet distinct efforts of all, beneficial results will certainly be accomplished. We of the Louisiana State board shall always be found ready to co-operate, to the utmost limit of our power to do so, in all measures having in view the interest and welfare of our common country.

Prior to the unanimous adoption of this report by the State board, Dr. Chaillé urged upon its attention the fact that the adoption of the Ship Island proposition could not possibly prove so disastrous that Louisiana "would be entirely ruined and would soon disappear from the family of States"; for in 1880 there had not been a single vessel, and in no one year had there ever been recorded more than six vessels which presented such evidence of infection that the National Board of Health would have required them to go to Ship Island. In proof that these were the views of the National Board of Health, a letter to the above effect from its president was read. None the less the vote taken on the report after this information was given was unanimous. The fact and the need for correcting various misapprehensions on the subject rendered necessary the following:

*Reply to the above, read at the meeting of the Louisiana State board, held June* 9, 1880.

To the Louisiana State Board of Health:

GENTLEMEN: In your report, adopted May 19, in reply to the five propositions of the National Board, submitted to you on May 13, you use the following encouraging *language*.

"We consider it our duty, we deem it is due both to ourselves and to our fellow-brothers of the National Board, to give fully and explicitly our honest opinions and convictions on subjects of such vital importance as those that relate to public health. We hereby reiterate our most earnest desire to extend our friendly relations with all sanitary organizations—with the National Board more particularly. The object we are striving for is the same; public health is our aim and ambition." "We of the Louisiana State board shall always be found ready to co-operate, to the utmost limit of our power to do so, in all measures having in view the interest and welfare of our common country."

The present representative at New Orleans of the National Board heartily reciprocates these sentiments, which encourage him to believe that you will patiently listen to some "honest opinions and convictions" opposed to your own, and that you are as anxious as he is to rid every question between you and the National Board of all misapprehensions and false issues.

On one subject, which may be termed the Eadsport and Ship Island quarantine question, it is respectfully but firmly believed that your report gives proof of serious misapprehensions respecting the position of the National Board on this question. Inasmuch as this same position has been taken by the sanitary council of the Mississippi Valley, and also by the Auxiliary Sanitary Association and the Medical and Surgical Association of New Orleans, it is not likely that disscussion will cease until all misapprehensions have been removed, and some general conclusion has been reached on the true issue. As to what I may say on this subject, I beg leave to remind you that, although I represent in this city, for the summer only, the National Board, I still remain one of your constituents; that, as a citizen of New Orleans, my love for it, my home reputation, and my money interests, all located here, greatly exceed any temptations which the National Board could possibly present me; and, therefore, that my convictions are not those of a salaried partisan, but of a fellow-citizen who has the permanent welfare of New Orleans nearest his heart, and who cannot be in any way so greatly benefited as by promoting its prosperity.

You have refused the request of the National Board—that you would co-operate with it in not permitting vessels "infected or furnishing reasonable grounds for suspicion of infection" to pass Eadsport without evidence that they had been thoroughly disinfected at the Ship Island quarantine station, for the following reasons, as expressed in your report or in the discussion which followed: Because it would be illegal to grant this request; because vessels would forfeit their insurance policies; because the commerce of New Orleans would be so destroyed that even Louisiana would be ruined; and because the Ship Island quarantine could not furnish protection as efficient as is given by your own Mississippi River quarantine station. These four reasons for your refusal will now be considered.

### 1.—THE ILLEGALITY.

On April 12, 1880, you referred this question to the Hon. J. C. Egan, attorney-general, who, on April 22, thus replied: "I consider that for the purpose of quarantine it would be in the power of your board to order ships coming to this port back to Ship Island as a condition to their entry, if, in your opinion, such a measure would tend to the better security of the State from infectious diseases." In addition to this official opinion I have consulted three of the most distinguished legal firms in this city, and all of them agree, even a member of one of these firms who doubts the expediency of such action, that your board has the power in question. The Hon. T. J. Semmes expressed his opinion in these words: "The State board of health has the power to exclude vessels from entering the Mississippi River, and as a necessary consequence can prescribe the terms of admission." My confidence in these opinions is so firm that nothing, unless a contrary decision by our highest courts, is likely to shake it.

The attorney-general adds to his conclusion the opinion that you ought not, without the personal service of your own agents, to regard the certificate of the chief medical officer at Ship Island as "conclusively satisfactory." No one has called in question your power and right, on making the requested concession, to impose such conditions as may be proper. The National Board would cheerfully consent to your posting one of your own inspectors at Ship Island itself, as well as at Eadsport, who, with your officers at the Mississippi River quarantine, could certainly furnish such additional evidence as would be "conclusively satisfactory" to you.

Finally, on this question of legality, it is worthy of your attention that local boards in adjacent States have not been embarrassed by it. By some of these boards infected vessels have been prohibited, until after their thorough disinfection at Ship Island, from entering their ports; by this measure, the only practical one, these boards have enforced the advice of the National Board, which has never attempted itself to exercise any forcible compulsion, either on local boards or on infected vessels.

### 2.—FORFEITURE OF INSURANCE.

The same legal firms were consulted on this question, and the reply was unanimous that vessels refused admission by you to the Mississippi River and advised to proceed to the quarantine at Ship Island would not by their compliance forfeit their policies. My attention was called to the highest authorities on the law of marine insurance, to Parsons, Phillips, Arnould, and Kent, all of whom substantially agree that a policy is not forfeited unless the vessel deviates without adequate cause from its prescribed route; that "no act done under compulsion can be regarded as a deviation"; that the orders of officers of a State are compulsory; and that compulsion, even if illegal, protects the policy from forfeiture.

Four of the most noted presidents of our most respectable insurance companies were also consulted, and these likewise united in the opinion that vessels would not forfeit their insurance policies. They added that, should your board take the action required by the National Board, the underwriters in this city could take instant action to quiet every question; and that the same action could be taken, with brief delay, by underwriters in other ports whether domestic or foreign.

This evidence has satisfied me that vessels, if required by you, whether indirectly or directly, to proceed from Eadsport to Ship Island for quarantine purposes, would not forfeit their insurance policies; and that if there were any such danger, the remedy would be promptly and easily found.

### 3.—DESTRUCTION OF THE COMMERCE OF NEW ORLEANS.

You are requested to prohibit the passage above Eadsport of any vessels whatever, except only those "infected or furnishing reasonable grounds for suspicion of infection." The amount of injury to commerce will depend on the proportion which the number of such vessels bear to the total number of vessels entering the Mississippi River. It is believed that the number of the latter has varied during the past ten years from about 800 to 1,300 annually. To estimate the number of the former I have examined the evidence for the past ten years in the annual reports of your board, and have found that these contain nothing whatever to indicate that there has ever arrived in any one year more than six vessels, either infected or which would have been under any interpretation suggested by the National Board reasonably suspected of infection. Your report for 1880 is the most satisfactory one on this subject yet published, and is for an unusually prosperous year. Out of 1,271 vessels entering the Mississippi River you did not deem it a wise precaution to detain more than the exceptionally large number of 151, and of these there was not one which was either infected or reasonably suspected of infection. Only one vessel out of the total 1,271—the bark Excelsior—ever gave any evidence either of infection or of reasonable suspicion of infection; and your own report also shows that there was no evidence of this at Eadsport, nor until this vessel reached New Orleans. Now, it is respectfully submitted that the detour of not exceeding six vessels annually from Eadsport to Ship Island and back could not prove by any means disastrous to the commerce of New Orleans.

It may well be urged that the phrase "reasonable grounds for suspicion of infection" is a very elastic one and liable to great abuse. But no one has disputed your power to fix precise limits to the signification of this phrase, and to assign to duty at Eadsport your own inspector, together with an inspector of the National Board, with orders to enforce no interpretation except your own of this phrase. It has never been denied that you alone have all the power in this matter, and therefore can dictate your own conditions. An inspector of the National Board at Eadsport could not, under present laws and regulations, exercise any more power there than its inspectors now at New Orleans and at the Mississippi River quarantine station exercise at these places, unless you saw fit to delegate to him some part of your own power. Surely it would be easy to check, when and how you pleased, the least tendency to injure the commerce of this city, whether this tendency was or was not justified by wise precautions for the public health.

These facts satisfy me that the injury to our commerce would prove insignificant in comparison with the popular misapprehension on the subject, and slight in comparison with the good it is believed would ensue.

### 4.—SHIP ISLAND QUARANTINE NO ADDITIONAL PROTECTION.

The National Board long since declared that it had no desire to "abolish the State board," nor to usurp "the power and authority conferred upon it by law," nor cause you "to abandon the fulfillment of your sworn and sacred duties," nor to impair the resources of your board. On the contrary, the National Board would rejoice to see your power and resources increased; for, disregarding less selfish consideration, is it not evident that, since it is a paramount duty of the National Board to aid and co-operate with local boards, the greater the influence of these the greater must be its own?

The National Board has requested you to co-operate with it in providing New Orleans with what, it is believed, would prove an additional protection to the public health, and urges this for the sake, not only of this city, but also of many adjacent communities who firmly believe themselves in constant danger whenever New Orleans becomes infected. Would the Ship Island quarantine, as a station of refuge for infected vessels, furnish any additional protection? Stripping the disagreement between the two boards of all misapprehensions and false issues, this, in my opinion, is the sole question for consideration.

On May 8 I inspected your Mississippi River quarantine station, and testify, with pleasure, that I found it better than I had expected, and that I detected nothing to indicate that the officers in charge were not discharging their duty to the best of their ability, and as efficiently as the circumstances and the means at their disposal permitted. But I think that our future protection demands that these circumstances and means should be fully appreciated, for thus only can our legislature be induced to give you the liberal aid required, and thus only can we secure from others needed sympathy and aid.

You report that Louisiana has on the Mississippi River "the best equipped and organized quarantine station outside of New York." As I have not inspected all of the others I cannot add my testimony to yours, but I do know that no place in the United States has proved itself as liable to yellow fever as has New Orleans, and, therefore, that our quarantines should be second to none in efficiency. Dispensing with minor criticisms, I found two very great defects at the chief one of our three quarantine stations.

First. If there be any police force it is inadequate to prevent communication between the quarantine grounds and the neighborhood; it is inadequate to prevent the passengers and crews of infected vessels from communicating with uninfected vessels and with the residents below, above, and over the river opposite to the station; it is inadequate to prevent such passengers and crews from occasionally avoiding at Eadsport or elsewhere your quarantine and in reaching this city by towboats or otherwise; and it is inadequate for the protection of Eadsport itself, as testified by Capt. James B. Eads in his letter published this day in the Democrat. Unless more amply provided with funds I do not believe it in your power to remedy this defect.

Second. Sanitation demands the thorough cleansing of an infected vessel, and this necessitates the discharge of its cargo, while commerce demands that these things shall be done promptly and economically, and these demands require an abundant supply of cheap labor. When inspecting the Mississippi River quarantine station I found one vessel paying $6 a day to every laborer, and the number secured by importation from New Orleans was inadequate, even at this price, to insure the thorough and prompt unloading, cleansing, and reloading requisite for the conjoint interests of sanitation and commerce. This grave defect is also out of your power to rectify. Nevertheless, however powerless you may be respecting the two defects cited, sanitarians and merchants, or both, will remain dissatisfied until some remedy for them is found.

The first defect is so inseparable from quarantine stations on the mainland that sanitarians unite in demanding their location on islands. Beside this inestimable advantage, I have been assured that an ample supply of laborers can be obtained at Ship Island for $35 a month. Further, I have much more confidence in the ability and will of the United States to make its station at this island as perfect as is practicable than I have in your gaining either from the legislature of this impoverished State or from the council of this impoverished city the aid necessary to perfect our three quarantine stations—an end which must be accomplished, unless we are to continue tampering with half-way measures. Appreciating fully our great misfortune that Louisiana has no island for a quarantine station at the mouth of our river, and that Ship Island is so distant therefrom, and conceding that the three reasons now given in favor of this station may not be considered conclusively satisfactory, I will advance an additional reason, which, combined with the others, has sufficed to convince me that good policy dictates concession to the request of the National Board. The health authorities of the adjacent States of the Mississippi Valley demand this concession as necessary to their protection, and declare that, if their demand is not heeded, they will be forced to interrupt our commerce with them on the least suspicion of danger. Yellow fever is a public enemy, and our neighbors have as much right to a voice in its exclusion from the Mississippi River as upon the exclusion therefrom of any other public enemy. Louisiana has not hesitated, when to its advantage, to vociferate that the Mississippi River is a national highway, and that all the States should contribute to its jetties and levees; now, when other States demand what they think essential for the protection of their health, shall Louisiana inconsistently reply that the mouth of this national highway is exclusively under its control, and shall be managed regardless of their wishes?

### 5.—GENERAL CONSIDERATIONS.

Several additional considerations deserve attention. Should our hope of greatly increased prosperity be fulfilled, then it is certain that our unacclimated population will increase, and thereby our danger of infection and our need for additional protection. Further, our traveling facilities will also be notably increased; with this the danger of infecting our neighbors, and with this their demands for better protection. These anticipated conditions will, it is to be hoped, continue to strengthen the pressure both within and without this city to keep itself clean and uninfected, and to adopt every reasonable precaution to attain these ends. Hence, it is idle to expect the present issue will die out, and if it be not met fairly and generously, then, when disaster overtakes us, as it may in spite of all efforts and concessions, New Orleans will find itself a helpless victim to the indignant distrust and hostile action of its neighbors. In this matter the National Board represents not only a large number of your fellow-citizens, and, in my belief, the health authorities of adjacent States, but also the same generous country which overwhelmed this city in 1878 with millions of dollars of bounty. Is it fitting to refuse a concession urged by such applicants, and to attribute to a mean spirit of commercial jealousy their anxiety to shield timid communities, which are not hardened by habit to our dreadful scourge, nor protected as we, in large numbers, are by acclimation? They ask no more than an apparent sacrifice of an insignificant fraction of our foreign tropical trade in lieu of what they deem better security both for them and for us, and in lieu of annual jeopardy to our inestimably more valuable interstate commerce. For my part, I advocate proving to our neighbors that we love them as ourselves, and I therefore would concede to them a voice, though opposed to our own, in controlling the importation of yellow fever into the mouth of our great national highway.

Your concession would result, I am confident, in diminishing our risks of infection, and thereby would tend to promote our growing grain trade, our European imports, our home manufactures, and our languishing summer business. Your concession would certainly accomplish the very desirable end of giving notice—as apart from the consideration of an inspector at Eadsport, should, I think, be given by you—to all owners, agents, and captains that vessels certainly infected shall no longer be permitted even to enter our river, but must, when destined for the Mississippi, proceed directly to the refuge for such vessels at Ship Island. By such measure you would teach them a much-needed lesson, namely, to enforce that better sanitary construction and regulation of their vessels which has enabled some steamship lines to ply between Havana and New York for a decenniad without having had a single case of yellow fever on board. This good result alone weighs heavily in the balance against the slight temporary injury to our commerce, and would, by permanent advantages, ultimately more than compensate this commerce.

Further still, your concession would give you greater influence in eventually promoting measures most desirable for our commerce; such, for instance, as gaining the aid of the United States in establishing quarantine stations perfectly satisfactory both to adjacent States and to Louisiana; and such as the stationing of sanitary officers both at Rio and Vera Cruz, whereby our intercourse with these ports would be rendered much safer, and the interests of our coffee and other trades would be greatly promoted.

In conclusion, gentlemen, it is my conviction that this question merits your further consideration, your personal inspection of the Ship Island quarantine station, and of all the subjects pertaining thereto, and that you would give great satisfaction to many of your fellow-citizens, within and without this State, should you consent to reconsider your refusal, based on what I have now stated my reasons for believing, were misapprehensions of the position on this subject of the National Board.

Very respectfully, yours,

STANFORD E. CHAILLÉ,
*Supervising Inspector National Board of Health.*

On June 16 Mr. I. N. Marks, the president of an insurance company and a member of the State board, read before it the following communication in support of the position taken on the subject by the board:

My position on the insurance question, as connected with the Ship Island quarantine, has not been properly stated.

I do not claim that if compulsion or force was used by the National or State authority in sending a vessel from the mouth of the river to Ship Island that such deviation in the voyage would vitiate the insurance on vessels and cargo if an accident occurred during the deviation.

I lay down the following propositions:

1. That neither the National or State board of health has the legal right to compel an infected vessel or one having the suspicion of infection, destined to the port of New Orleans, to deviate from her direct voyage and proceed to Ship Island or any other point outside of the territory of Louisiana.

2. That such legal power not being vested in the State board of health of Louisiana, that the captain of a ship, taking it from the mouth of the river to Ship Island on the *simple order* of an officer of the board of health, would be (on his part) performing a *voluntary* act.

3. That apart from the illegality of any such order, the necessity for a compliance with it or for its execution does not exist.

4. That the State of Louisiana has (under its laws) provided a well-ordered, thoroughly-equipped, and efficient quarantine station to which all vessels from infected ports must go for detention, inspection, fumigation, and disinfection.

5. That, the foregoing being admitted, it would be unwise and unnecessary to attempt to illegally force a vessel to proceed to a place unfit, from its geographical position, its proximity to the thickly-inhabited coast of Mississippi, its constant intercourse with the inhabitants of said coast, its want of a safe anchorage for vessels, its constant exposure to storms, for quarantine purposes.

6. That if the captain of a vessel, in the absence of physical force, and in the face of the want of a necessity for the act, takes his ship from Eadsport to Ship Island, in the eyes of the law he voluntarily deviates from his voyage, and vitiates the insurance on vessel and cargo.

7. That if the State board of health possessed the physical power (and it does not) to forcibly take a vessel to Ship Island, and an accident happened to said vessel, and the insurance company paid the loss, the said company could, in my opinion, recover from the board of health the amount involved, on the just ground, that the loss had been occasioned by an illegal act on the part of said board.

The foregoing propositions I distinctly lay down and maintain.

The writer in the Democrat, whose communication I have read, makes certain extracts from Philips and Parsons on Marine Law, giving only such portions of such sections quoted as suits his purpose, suppressing or withholding the more important (in this case) conclusions. He quotes as follows:

Philips says: "The doctrine of deviation has reference to voluntary acts or to neglect, and not to unavoidable interruption of the voyage." Vol. —, sec. 984, page 565.

Philips does not terminate his section as above, for at the word "voyage" he uses a semicolon, and not a period, as S. quotes it, and then goes on to explain his opinion by adding: "Such as, the vessel being driven from the course in a storm, or being taken possession of by a mutinous crew. But in case of a master of a vessel going out of harbor, by order of the captain of a frigate lying near, to examine a strang sail, Lord Ellenborough ruled it to be a deviation, remarking that if he had gone by by compulsion, and under threat or just fear of violence, it would not have been so."

Philips again says, sec. 983, page 566, vol. 1: "It is not necessary to a deviation or change of risk, whereby the underwriters are discharged, that the degree or period of the risk should be thereby increased. The assured has no right to substitute a different risk."

S. quotes from Parsons as follows: Parsons says, "Deviation applies only to a voluntary act. The definition shows that any change which can be justified or shown to proceed from a just cause is not deviation." Vol. 2, sec. 5, page 28.

Parsons continues: "And of course no act done under compulsion can be regarded as a deviation. The change of risk, to operate as a deviation, must not be only voluntary but unnecessary; or, rather, if it be necessary, it must be considered as compelled rather than as voluntary."

From the foregoing it seems perfectly clear that the attitude of this board upon this question is correct, legal, and rational.

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### *Second proposition in reference to the Eadsport and Ship Island quarantine question.*

NATIONAL BOARD OF HEALTH,
*New Orleans, La., June* 16, 1881.

Prof. JOS. JONES, M. D.,
*President Louisiana State Board of Health:*

DEAR SIR: In the event that your board declines to reconsider its refusal (May 19) of the application (May 13) of the National Board for permission to station at Eadsport an inspector, with power to prohibit infected vessels from entering the Mississippi River until after their thorough disinfection at the refuge station at Ship Island for such vessels, it is respectfully urged that your board consider the expediency of adopting such measures as would tend to cause infected vessels bound for the Mississippi to proceed *directly to the Ship Island quarantine station* for thorough disinfection prior to attempting to enter the mouth of said river. This result might be accomplished by the adoption of a regulation prohibiting vessels which have any cases of yellow fever on board, or which have had any such cases while either at the port of departure or *en route* from passing into the Mississippi until such vessels, very few in number, have been thoroughly disinfected at Ship Island.

The public advertisement of such a regulation, together with the notification thereof of pilots and of consuls, would promptly diminish to the utmost the inconvenience to commerce, and it is believed that ample power to execute such a regulation will be found in section 1 of the act of Congress "to prevent the introduction of contagious and infectious diseases into the United States," approved June 2, 1879.

Such a regulation would cause three good results: It would induce those who control vessels bound to this port to adopt better sanitary measures for protecting their vessels from becoming infected; it would furnish additional protection to this city; and it would very surely give an additional feeling of security and great satisfaction to all communities in close commercial intercourse with New Orleans.

Very respectfully, yours,

STANFORD E. CHAILLÉ,
*Supervising Inspector.*

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OFFICE BOARD OF HEALTH, STATE OF LOUISIANA,
*New Orleans, June* 23, 1881.

Dr. S. E. CHAILLÉ,
*Supervising Inspector National Board of Health:*

DEAR SIR: I am instructed by the president of the board to acknowledge receipt of your two communications of recent dates: one relative to a steam-launch for the use of Dr. Patton at the Mississippi quarantine station, the other relative to sending infected vessels to the Ship Island quarantine. The communications were read by the president to the board, but no action was taken thereon, the president being simply requested to acknowledge the receipt of the same.

Respectfully, your obedient servant,

[L. S.] S. S. HERRICK, M. D., *Secretary.*

The above was the only reply ever received to the preceding and following letters, except that Dr. Jones stated verbally that he doubted the board's power to appoint a sanitary policeman on the United States steam-launch, and that he did not admit that there was any improper communication rendering it necessary.

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NATIONAL BOARD OF HEALTH,
*New Orleans, La., June* 10, 1881.

Dr. JOS. JONES,
*President Louisiana State Board of Health:*

DEAR SIR: In case I should apply to the National Board of Health for permission to send its steam-launch to Mississippi River quarantine for the use of our officers there, would you agree to place on it a sanitary policeman, with authority to use said launch for, among other purposes, preventing improper communication with said quarantine station and with New Orleans?

I believe that, with this understanding, the permission might be given me.

Yours, very truly,

S. E. CHAILLÉ,
*Supervising Inspector.*

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## APPENDIX 6.

OFFICE OF THE SUPERVISING INSPECTOR OF THE
NATIONAL BOARD OF HEALTH,
*New Orleans, May* 24, 1881.

DEAR SIR: It has been made my primary duty, as "the representative and chief executive agent" in this city of the National Board of Health, to obtain the earliest possibly information of the existence of yellow fever in New Orleans or its vicinity. To fulfill this duty, I am instructed, among other measures, *to endeavor to secure* from the "physicians of New Orleans and the river parishes below New Orleans," and from the "sanitary and medical organizations of the city," prompt information "as to the presence of cases of yellow fever, or of doubtful or suspicious cases of this disease."

There are three considerations which deserve your attention when determining the question whether you will contribute this information. First, the health authorities of neighboring States insist that prompt notification of the whole truth respecting the appearance of yellow fever in New Orleans is indispensable for their own protection, and warn us that any failure to furnish this information will force them so to act that far greater detriment would thereby result to this city than from reports of all the facts. Second, all must concede that, if the spread of yellow fever can be prevented, sanitary measures should be speedily applied to the very earliest cases, whether real or reasonably suspected. Third, the laws of Louisiana, as well as the regulations (authorized by the laws of the United States) of the National Board of Health, inferentially declare that yellow fever is a portable disease, inasmuch as they provide means to prevent its importation and its spread, and the ordinances of the city of New Orleans enforce the same view by enjoining the prompt report of all cases of this disease to the State board of health; hence all law-abiding physicians and citizens are bound to facilitate the application of these measures, even though they, in some instances, may be convinced that our laws are founded in error, and that no available measures can be or will be applied to prevent the importation and spread of yellow fever.

The facts justify this application to you for the aid indicated, and while you are under no legal obligation to give this aid to a sanitary officer of the National Board of Health, it is none the less believed that your compliance would not only promote the public welfare and the interests of science, but would also relieve you, in respect to the public health, from a very grave responsibility officially imposed on others.

Where the objection of the patient or of his attending physician would make my inspection of the former, in company with the latter, unadvisable, the attending physician is earnestly requested to keep and promptly to report a careful record of the history of every case which he knows or fears to be yellow fever; and the same course is deemed very desirable respecting all cases of hæmorrhagic malarial fever, or other fevers which simulate yellow fever. Any summons for or report to me should be sent to my office, in the third story of the University building, at the corner of Common and Baronne streets, or to my residence, No. 24 South Rampart street, between Common and Canal streets, and any necessary expense incurred therefor will be refunded. If there should be satisfactory cause to request it, Dr. S. M. Bemiss, resident member of the National Board, would, no doubt, consent to serve as my substitute in examining any cases or supposed cases of yellow fever.

In order that you may better understand the character and purpose of the aid requested, a printed copy of my official instructions is inclosed, to which, and especially to Appendix D, your attention is solicited.

Since it is most important that I should know what are to be the sources of information upon which I can rely, you are earnestly requested to reply to this communication, furnishing your full address (and, if in the country, the location of your practice), and stating whether you will be good enough to give the aid solicited.

Very respectfully, yours,

STANFORD E. CHAILLÉ, M. D.,  
*Supervising Inspector of the National Board of Health,*  
*P. O. Box 1689, New Orleans, La.*

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*Extract from a letter of the former health officer at Port Eads to Dr. Chaillé.*

"I wish to call your attention to matters pertinent to your circular. Quarantine is established in this State forty miles above Port Eads. Vessels from all parts of the world come to an anchor at this place and stay during their pleasure, many of them from infected ports. Often the captains, and sometimes their wives and children, come ashore and go to New Orleans, either on the mail-boat, tow-boats, or steamers. There is always more or less communication between the vessel and shore, persons go aboard, and there is no restriction upon intercourse.

"The customs officers and crew are not acclimated; they come and go with perfect freedom, and the custom-house is in the midst of the settlement."

Here follows a statement of a supposed case of infection by yellow fever on a vessel in 1878, and the exposure of Eadsport in the same year to small-pox infection.

"My object in writing the above is to impress upon you the importance of having some one here to represent the National Board of Health, or the State board, or both, with authority to board all vessels, especially those from infected places, and to prevent their remaining here. It seems to me that this place is liable to start an epidemic at any time, and if there is any virtue in quarantine restrictions here is the place to commence work. Your representative here should have a boat and boatman, and should go to each vessel. I assure you this is a very important matter, and in my humble opinion your quarantine regulations are very defective without this place being guarded against.

"J. H. STOCKLEY,  
*"Former Health Officer to Jetty Company,*  
*"Port Eads, La., May 30, 1881."*

### EVIDENCE OF DR. RYAN.

*Report of the proceedings of the Louisiana State board of health on July 28, from the Daily Picayune of July 29, 1881.*

"A communication was read from Dr. Ryan, quarantine physician at Port Eads, stating that the telegraphic operator there boarded every vessel which arrived, and that the officers and employés of the custom-house, after boarding vessels from infected ports, occasionally arrived in New Orleans some days before the vessel. Dr. Jones stated that the operator had no authority whatever from the board to board vessels, and that the collector of the port would be notified of the charge made against the officers and employés of the custom-house at Port Eads."

On July 28 the State board "*Resolved*, That a committee of three be appointed by the president to investigate the discretionary powers of the quarantine physician in regard to allowing acclimated persons to come up to the city from vessels from infected or suspected ports, and to draft recommendations for his guidance in such cases that come under section 3 of the act of March, 1855."

On August 11 the report of the committee was adopted, and was as follows:

"Your committee, after a careful consideration of the whole subject, beg leave to report that, whilst they do not believe that Dr. J. F. Finney, resident physician at the Mississippi River quarantine station, has abused the power conferred on him by the act of 1855 relative to acclimated persons, still we consider the fact of allowing acclimated persons to hold communication with or to come from ships detained at the quarantine station to be of such grave importance to the public health of this city that the matter is one that ought to be under the immediate direction of this board: Therefore, be it—

"*Resolved*, That Dr. J. F. Finney, resident physician at the Mississippi River quarantine station, be instructed not to permit any person, acclimated or unacclimated, to leave any ship, for any purpose whatever, detained at the Mississippi River quarantine station, without a recommendation from Dr. Joseph Jones, president of the State board of health."

On August 18 a member of the State board reported to it, in reference to the Rigolets quarantine station: "Inspection is the gist of the whole matter, and this should be conducted very differently from the manner set forth in the sworn testimony before the board."

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## APPENDIX 7.

*Charges against Quarantine Inspector Patton.*

At the meeting of the Louisiana State board of health, September 15, 1881, Dr. Jones said he had been requested to read the following letters:

QUARANTINE STATION, MISSISSIPPI RIVER, LA.,
*September* 12, 1881.

Dr. STANFORD E. CHAILLÉ,
*Supervising Inspector National Board of Health:*

DEAR SIR: I have hereby to acknowledge the receipt of your letter inclosing extracts from New Orleans papers, in which my name occurs in a complaint made by Captain Calloway, of the British steamship Historian, to the State board of health as to the treatment of his vessel at this station and the conduct of the quarantine officers. As to his charge that I am in the habit of visiting the Buras settlement, I have to state that I have occasion to do so at least three or four times every week, as there is no post-office nearer.

I have had no "guests" in the sense implied by Captain Calloway. Early during my stay here my wife was with me for several weeks, and since her departure two other members of my immediate family, my wife's young sisters, have been keeping house for me. They are here with the consent of Dr. Finney; they have nothing to do with quarantined vessels, and as, in addition, they are acclimated, I can see no possible objection to their presence. I make this explanation to you, though in general I would not feel called upon to explain matters affecting solely my private domestic arrangements. As regards the charge that I telegraphed that a suspicious case of fever had occurred on the steamship Historian, you know yourself that this is utterly false, and you have my authority for so denouncing it through the press if you so prefer.

In conclusion, I beg to remain yours, very respectfully,

G. FARRAR PATTON, M. D., *Inspector.*

NATIONAL BOARD OF HEALTH,
*New Orleans, September* 14, 1881.

Prof. JOSEPH JONES, M. D.,
*President Louisiana State Board of Health:*

DEAR SIR: In justice to Dr. Patton, inspector National Board of Health, I would be obliged if you would have read at the next meeting of your board his inclosed communication [as above] in reply to the charges publicly made against him by Captain Calloway at the session of your board on September 8.

Respecting the charge that Inspector Patton reported a suspicious case of fever on Captain Calloway's vessel, I confirm Dr. Patton's denial of said charge as false.

As to the charges that he improperly visits the Buras settlement, and entertains "guests" at the quarantine station, I would be obliged if your board would indicate whether Inspector Patton has in any wise violated, in view of his statement of the facts, any laws of this State, or any of the rules and regulations of the Louisiana State board of health, which laws and regulations it is the imperative duty of all inspectors of the National Board of Health to comply with.

Yours, very respectfully, STANFORD E. CHAILLÉ,
*Supervising Inspector National Board of Health.*

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[Neither of the two communications immediately following were forwarded to nor received by the supervising inspector until October 3.—S. E. C.]

*Extract from the minutes of the board of health State of Louisiana at its meeting September* 15, 1881.

A communication from Dr. Chaillé, supervising inspector of the National Board of Health, was read, accompanied by a copy of one from Dr. Patton, inspector of the National Board at the Mississippi quarantine. Dr. Patton asserted that his alleged guests at the station are members of his family, residing there by permission of the resident physician, and fully acclimated. He has to visit Buras two or three times a week, as it is the nearest post-office.

The president held that Dr. Patton had violated the law.

The board was censured last year on account of communication between the station and Buras.

The president stated that, after the charges of Captain Calloway, of steamship Historian, had been made before the board, he had called upon the governor, his excellency Louis A. Wiltz, and inquired whether any permission had been granted to the supervising inspector of the National Board of Health stationed in New Orleans, or the inspector of the National Board of Health stationed at the Mississippi quarantine, to introduce any parties either as guests or as the crew of a steam-launch upon and within the grounds of the Mississippi quarantine station. The governor stated that he had not granted such permission. After obtaining this information, he had addressed a letter to Dr. Finney, quarantine physician, Mississippi station, making inquiry into the questions involved; up to the present date no reply has been received from Dr. Finney; but, when received, it will be laid before the board at the regular meeting.

In reply to an inquiry addressed by Dr. Jamison, whether the inspector of the National Board of Health had violated the laws of the State, the president said that by sec. 6 of "An act to establish quarantine for the protection of the State," approved March, 1855; sec. 1 of "An act supplementary to an act," approved March 18, 1858; and sec. 6 of "An act to establish quarantine for the protection of the State, to create a board of health, and to define its powers and duties," approved March 16, 1870, and sec. 7 of "Act 80, to reorganize and render more efficient the board of health of the State of Louisiana," approved April 20, 1877, the board of health was placed absolutely and unconditionally by the general assembly of the State of Louisiana in charge of the Mississippi quarantine station, and of all others within the limits of the State; and no one, whether an inspector or supervising inspector or member of the National Board of Health, had the right to introduce people under any pretext whatever within the quarantine stations of the State without the permit of the board of health, and in accordance with the rules and regulations of the board of health governing quarantine stations. (See codified acts of legislature and rules and regulations of board of health, pp. 51 and 52.)

Dr. Formento and Mr. Brewster found no violation of law on the part of Dr. Patton.

Dr. Jamison thought Dr. Patton's sense of propriety ought to guide him there.

Mr. Booth introduced a resolution on the subject, which was rejected by the following vote:

*Ayes*—Jamison, Marks, Booth.

*Noes*—Formento, Bean, Hernandez, Lanaux, Brewster.

A true copy. S. S. HERRICK,
*Secretary Board of Health.*

OFFICE BOARD OF HEALTH, STATE OF LOUISIANA,
*New Orleans, September 6, 1881.*

Dr. JAMES F. FINNEY,
*Resident Physician Mississippi Quarantine Station.*

DEAR SIR: The board of health of the State of Louisiana has received information to the effect that G. F. Patton, M. D., inspector of the National Board of Health, has entertained, and is now entertaining, upon and within the limits of the quarantine grounds of the State of Louisiana, one or more individuals, and also that the said inspector of the National Board of Health keeps a steam-launch, with one or more men, at the Mississippi quarantine station, and that in company with his guests, and with the crew of his steam-launch, holds communication with the inhabitants of the opposite bank of the Mississippi River, in the village known as the Buras settlement.

As Dr. G. F. Patton, inspector of the National Board of Health, was upon the request of the executive committee of the National Board of Health permitted by the governor of Louisiana to reside at the quarantine station for the purpose of furnishing, under certain definite conditions, information as to the absence of yellow fever and the sanitary condition of the shipping, the president of the board of health of the State of Louisiana visited his excellency Governor Louis A. Wiltz, and inquired whether permission had been granted to the inspector of the National Board of Health to entertain guests at the Mississippi quarantine station.

His excellency Governor Louis A. Wiltz stated that he had granted no such privilege to the inspector of the National Board of Health, and that he had been permitted to reside at the Mississippi quarantine station in accordance with the proposition enunciated in the communication of Prof. J. L. Cabell, M. D., president of the National Board of Health, addressed to the president of the State board of health, on the 19th of February, 1881.

His excellency Governor Louis A. Wiltz regards the inspector of the National Board of Health, residing by his permission at the Mississippi quarantine station, as subject to the quarantine laws of the State of Louisiana as embodied in the organic acts of the legislature, and he holds that his permission granted to the National Board of Health may at any time be revoked.

Your attention as resident physician of the Mississippi quarantine station is directed to the following proposition contained in the letter of Prof. J. L. Cabell, M. D., president of the National Board of Health, of February 19, 1881.

* * * * * * *

"1st. That an inspector of the National Board of Health be stationed at the Mississippi quarantine for the purpose of observation and inquiry, who shall have the privilege of inspecting, in company with the quarantine officer, all vessels arriving at the station, and who, in the event of the difference of opinion between himself and the quarantine officer as to the actual sanitary condition of such vessels and as to the treatment which they require, shall send to the president of the State board a copy of the report made to the National Board."

No other terms have been considered, either by his excellency the governor, or by the board of health of the State of Louisiana, with reference to the presence of an agent of the National Board of Health at the Mississippi quarantine station, than those just quoted as enunciated by the executive committee of the National Board of Health through its president.

The resident physician of the Mississippi quarantine station will therefore, in view of the preceding facts and statement, furnish the board of health of the State of Louisiana specific replies to the following questions:

1. Has the inspector of the National Board of Health, stationed at the Mississippi quarantine station in accordance with the permission of Governor Wiltz, conducted himself in accordance with the terms laid down in the propositions of the National Board of Health just quoted? If he has not, give full particulars.
2. Has the inspector of the National Board of Health introduced any guests or employés within or upon the quarantine grounds of the State of Louisiana at the Mississippi quarantine station; if so, by whose permission have said individuals been inintroduced within the boundaries of the quarantine as established by the laws of Louisiana?
3. Has the inspector of the National Board of Health violated the laws of Louisiana by holding communications with vessels from infected ports and with the inhabitants of the opposite bank of the Mississippi River?
4. Has the inspector of the National Board of Health had yellow fever?
5. Have the individuals alluded to as his guests and employés ever had yellow fever?

The resident physician at the Mississippi quarantine station is respectfully urged to forward his replies to the above inquiries at the earliest practicable moment.

Respectfully,

JOSEPH JONES, M. D.,
*President Board of Health State of Louisiana.*

**[The following letter was published September 30, as a part of the proceedings of the Louisiana State board on September 29.]**

MISSISSIPPI QUARANTINE STATION, *September* 13, 1881.

JOSEPH JONES, M. D.,
*President Board of Health State of Louisiana:*

DEAR SIR: Your communication of the 6th instant has been received, and in answer to the questions therein contained I respectfully make answer as follows:

1. In reference to the inspector of the National Board of Health at this station conducting himself in accordance with the terms of the proposition of the National Board of Health to the State board, he certainly has not, and in more instances and ways than one. In the first place he has exceeded the bounds of his duty and the (superficial) object of his appointment in his letter to the representative of the National Board at New Orleans, containing comments on the expense to vessels from Rio de Janeiro in undergoing quarantine at this station, and suggesting as a remedy that all vessels from Rio be advised through the United States consul at that port not to trade with New Orleans from May to November of each year. In this same letter no complaint is made of the inefficacy of the system of disinfection and purification of these vessels at this station, but objection is raised to the having to truck cargoes of coffee a distance of 300 feet from the vessel to the warehouse (on the ground of expense), during which process such verification of the cargo is acquired as could be obtained in no better manner. I fail to see anything in the terms of the proposition of the National Board which justifies its inspectors at this station to make inquiries into the expense incurred by vessels subject to quarantine regulations of this State, and still less that he should take upon himself the responsibility of advising vessels from Rio to cease their intercourse with us, and consequently destroy our commercial relations with this port.

Now, as to the expense of vessels from Rio in undergoing the quarantine at this station, they are certainly as reasonable as those of any other port where similar measures of purification, disinfection, and fumigation are resorted to; and, furthermore, this expense is generally borne by the consignees of the cargo and not the vessel, and costs about 3 to 4 cents a bag, which amount surely cannot affect the coffee market to any great extent. The inspector of the National Board of Health at this station has not conducted himself in accordance with the proposition of the body he represents, inasmuch as he has seen fit to telegraph to the supervising inspector of the National Board of Health at New Orleans the existence of a suspicious case of yellow fever at this station without consulting the State quarantine officers in reference to the alleged case, without their knowledge in any respect, and without furnishing the State board of health with a copy of the report, and which report was not justified at all by the symptoms of the case at any time being, or subsequent developments. The inspector of the National Board has on other various occasions sent reports the contents or purport of which I have no knowledge. In answer to your second question, I have to inform you the inspector of the National Board has two men in his employ, both of whom reside adjacent to the quarantine grounds.

The guests of the inspector consisted of his wife, who spent a few days here with him about two months ago, and two little girls, sisters of his wife, who have been here now about four weeks; with whose permission I do not know.

Your third interrogatory I will answer by stating that the inspector of the National Board has not, to my knowledge, violated any specific law in regard to communicating with the inhabitants of the opposite bank of the river, inasmuch as there has been no contagious and infectious disease at this station since the inspector of the National Board has been here. In answer to the fourth question, the inspector of the National Board at this station has never had yellow fever, and this fact was known to the supervising inspector of the National Board at New Orleans at the time of the appointment of said inspector. Owing to the knowledge that said inspector had not had yellow fever, he was quarantined five days from the time of his last communication with any vessel before being allowed to proceed to New Orleans. In reference to your last question, I believe none have had yellow fever (of his guests) excepting one of the little girls now here; however, none of them have been on board of any vessel in quarantine.

Very respectfully,
J. F. FINNEY, M. D.,
*Resident Physician.*

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NATIONAL BOARD OF HEALTH,
*New Orleans,* ——— 5, 1881.

Prof. JOSEPH JONES, M. D.,
*President Louisiana State Board of Health:*

**DEAR SIR: Since Dr. G. F. Patton has been retired from the service of the National Board, and since I esteem him as a most trustworthy and capable officer, my sense of**

justice prompts me to defend one who was my subordinate from the accusations of Dr. Finney, quarantine physician, dated September 13, published on September 30, in the report of the proceedings on the 29th of the State board, and prompted by a letter of inquiry on the 6th from yourself.

Dr. Finney's charges commit great injustice by inference, omissions, and forgetfulness. No less than ten charges are made or referred to, and with each of these will be given its explanation.

1. It is charged that Inspector Patton did not restrict himself to the "terms of the proposition of the National Board of Health to the State board," to "the bounds of his duty," and to "the (superficial) object of his appointment." The terms of the proposition accepted by Governor Wiltz were, that an inspector of the National Board of Health should "be stationed at the Mississippi quarantine" for "purposes of observation and inquiry," and, as a matter of course, to report the result thereof. In my estimation, Dr. Finney entirely fails in his subsequent charges, now to be stated, to establish any foundation for this general accusation; and even if it were well founded, Inspector Patton simply obeyed orders to observe, inquire, and report upon everything concerning the Louisiana quarantine, whether commendable or otherwise, for which orders the National Board of Health was alone responsible.

2. Inspector Patton suggested as a remedy for the quarantine expenses incurred by vessels from Rio "that all vessels from Rio be advised by a U. S. consul at that port not to trade with New Orleans from May to November of each year." True, but Dr. Finney omits two important facts: First, that Inspector Patton stated in the same report how this warning should be given, namely, by timely official notice to vessels at Rio and destined to New Orleans of two simple facts, viz, of the duration of quarantine detention and of the consequent unavoidable expenses. So far as concerns this latter proposition, to which the former was subordinate, Inspector Patton advocated an unquestionably sound policy, calculated to benefit commerce, viz, that all foreign ports should be given timely official notice of the quarantine restrictions existing at all ports of the United States. Second, the first proposition, that is, the suggested "warning," was not approved by myself nor by any of Inspector Patton's superiors; information thereof was restricted to the National and the State board; it never did inflict and never could have inflicted the least injury on New Orleans, and would have remained an unregarded still-birth if Dr. Finney had not preferred to honor it with a public funeral. Farther, Inspector Patton did not, as Dr. Finney alleges, "take upon himself the responsibility of advising vessels from Rio" anything whatever; he really did no more than make a fruitless suggestion to the National Board of Health, which certainly is not a vessel. Inspector Patton objected to the expense of trucking cargoes of coffee to the warehouse. For what purpose? Not, as is implied, because this measure is not the best one now practicable, but in connection with his advocacy of a system for the future of sanitary barges as a substitute for the present warehouse system, the former system being calculated, in his opinion, to prove better both for public health and commerce.

4. Inspector Patton reported one suspicious case of fever at the station (and never but one, which occurred on the bark St. Olaf and not on the Historian, as falsely reported to the Board by Captain Calloway), and neglected not only to consult the State officers but also to report the case to the State board. As to this negligence Inspector Patton frankly admitted it, and accepted censure with characteristic manliness. But this negligence, though at the time unknown to me, was promptly rectified so far as concerned the State board by me, for I sent a copy of the telegram forthwith to the president of said board. Not only this, I sent the information in obedience to my instructions both to the secretary and to the superintendent of the Mississippi River service of the National Board of Health. Yet the panic which it had been charged would result from such a course did not ensue, as is well known; on the contrary, this course strengthened the confidence already felt in other States, that should real danger to them arise prompt information would be given.

5. Inspector Patton is charged with having "on various other occasions sent reports of the contents or purports of which I have no knowledge." Neither I nor Inspector Patton were ever ordered or requested to send reports to Dr. Finney, but copies of all official reports sent by Inspector Patton, and which concerned the sanitary officers of Louisiana, were sent by me to the State board.

6. Inspector Patton's two steam-launch employés resided outside of and immediately "adjacent to the quarantine grounds." Dr. Finney knows that this was unavoidable; that his own employés have the same daily communication with outside adjacent houses, and that Inspector Patton's employés were specially ordered to board no vessel without Dr. Finney's permission.

7. "Inspector Patton occasionally visited the inhabitants on the opposite bank of the river," *i. e.*, the Buras post-office. Yes, with the consent (no yellow fever being present) and generally in company with a State quarantine officer. In this I simply explain without defending, since I believe that other post-office arrangements should be made.

8. Inspector Patton entertained his wife and her two young sisters as guests "with whose permission I do not know," says Dr. Finney. But Inspector Patton remembers well that his wife's two young sisters had the permission of Dr. Finney, whose manly courage I have too much faith in to believe that he will deny in view of Dr. Patton's positive assertion that his own memory was probably at fault. In any case Dr. Finney has supreme authority at his quarantine station, and if in this or other matter Inspector Patton acted illegally or improperly, why did Dr. Finney permit him to persist in his illegality or impropriety, such as entertaining his wife twelve days in July, and her two sisters from July 18 to September 17, without a word of objection?

9. Inspector Patton has never had yellow fever. True, he has been curiously deprived of this blessing. But he has been repeatedly exposed during four different years, and among these to the unsparing epidemic of 1878; further, he was a State quarantine officer from 1877 to 1880, and no objection was found to the misfortune that yellow fever has refused to attack him until the ex-State officer became an officer of the National Board of Health.

10. Finally, of Inspector Patton's three guests, Dr. Finney says: "I believe none have had yellow fever excepting one." The truth is that two of the three have had undoubted cases of yellow fever, and the third, 17 years of age, has been a resident of New Orleans from early childhood, had a mild fever (not known to have been yellow fever) in 1867, and passed harmlessly through the epidemic of 1878. Further, Inspector Patton enjoyed no more privilege in this matter of guests than has always been accorded heretofore to the wives, &c., of custom-house and other officers temporarily stationed at the quarantine.

Dr. Finney omits another very important fact, namely, that prior to my appointment of Inspector Patton both he and the president of the State board expressed to me their perfect satisfaction with, and their decided preference for him. Carefully considering the charges now made against him, I find those which are well founded comparatively trivial, and recalling the numerous opportunities he has had for serious derelictions which he did not commit, I cordially thank Dr. Jones and Dr. Finney that the candidate recommended by them has been found by me worthy of their indorsement.

Dr. Finney's letter, with its attending facts (such as that his charges were not made when their causes were committed and when they might have been corrected, and that their publication was delayed to the day of Inspector Patton's relief from duty) prompt the belief that objections to Inspector Patton are altogether secondary to the far greater objection that there should in future be at the quarantine station any inspector whomsoever of the National Board of Health. However, above the minor issues which have been raised, issues readily adjustable since the National Board commands all officers to obey State authority, the questions of chief consequence to the public remain untouched, viz: Whether the presence of the inspector of the National Board of Health at the quarantine has tended to increase or decrease the vigilance which is the safeguard of our public health, and the confidence of those neighbors upon whom depends so largely the freedom of our commercial intercourse?

In conclusion, the National Board is likely to rejoice now at all such evidences as Dr. Finney presents of excessive quarantine vigilance and precaution, and to rejoice still more in future should proof be given that those who preach practice themselves and force all others, the officers of the National Board of Health included, to practice what is preached. By which remark it is not my intention to question the fact that much credit is due to the State board and to Dr. Finney for an improved and comparatively efficient, even if not as yet a perfect quarantine. Further, Dr. Finney, as also his assistant, Dr. Wilkinson, deserve cordial thanks for their courtesy and favors to the officer of the National Board of Health, and for their invariably harmonious co-operation with him in their daily work of disinfecting suspected vessels. For them personally no feeling other than kindly is entertained.

I trust my belief will be concurred in, that justice requires that the same publicity should be given this letter as was given by the State board to Dr. Finney's.

Yours, very respectfully,

STANFORD E. CHAILLÉ,
*Supervising Inspector National Board of Health.*

# APPENDIX 8.

## FOREIGN COMMERCE OF NEW ORLEANS WITH INFECTED AND NON-INFECTED PORTS.

*Table showing the total value, in dollars, of the merchandise (coin and bullion excluded) involved in the foreign commerce of New Orleans, and especially its commerce with all foreign countries habitually or frequently infected with yellow fever; compiled from the annual reports of the United States Bureau of Statistics for the three years, July 1, 1877, to July 1, 1880, the last report yet published.*

| | Foreign countries. | 1877-1878. | | Yellow fever, 1878-1879—epedemic. | | 1879-1880. | | 1877-1878. | Yellow fever, 1878-'79, epidemic. | 1879-1880. |
|---|---|---|---|---|---|---|---|---|---|---|
| A | Without the yellow fever zone. | Imports. | Exports. | Imports. | Exports. | Imports. | Exports. | Total imports and exports. | Total imports and exports. | Total imports and exports. |
| 1 | Great Britain | 2, 239, 848 | 46, 666, 172 | 1, 645, 679 | 32, 642, 433 | 3, 639, 569 | 50, 062, 342 | 48, 906, 020 | 34, 288, 112 | 53, 701, 911 |
| 2 | France | 88, 170 | 18, 712, 125 | 798, 965 | 11, 514, 505 | 682, 071 | 19, 834, 864 | 17, 502, 295 | 12, 313, 470 | 20, 516, 935 |
| 3 | Russia | .......... | 4, 098, 944 | .......... | 9, 034, 488 | .......... | 5, 215, 574 | 4, 098, 944 | 9, 034, 488 | 5, 215, 574 |
| 4 | Germany | 175, 543 | 6, 782, 565 | 96, 193 | 4, 147, 604 | 130, 416 | 4, 574, 384 | 6, 958, 108 | 4, 243, 797 | 4, 704, 800 |
| 5 | Italy | 116, 928 | 2, 496, 500 | 270, 781 | 1, 544, 323 | 284, 378 | 3, 114, 291 | 2, 613, 428 | 1, 815, 104 | 3, 398, 669 |
| 6 | Spain | 47, 333 | 2, 140, 095 | 38, 022 | 1, 725, 244 | 553 | 2, 255, 680 | 2, 187, 428 | 1, 763, 266 | 2, 256, 233 |
| 7 | Belgium | 470 | 1, 140, 059 | 1, 741 | 664, 863 | 65, 113 | 1, 690, 010 | 1, 140, 529 | 666, 604 | 1, 755, 123 |
| 8 | Netherlands | 31, 453 | 1, 172, 452 | 1, 134 | 808, 758 | 25, 631 | 1, 166, 905 | 1, 203, 905 | 809, 892 | 1, 192, 536 |
| 9 | Austria | 66 | 109, 050 | .......... | 194, 273 | 28 | 514, 614 | 109, 116 | 194, 273 | 514, 642 |
| 10 | Gibraltar | .......... | 618, 282 | .......... | 97, 550 | 325 | 359, 207 | 618, 282 | 97, 550 | 359, 532 |
| 11 | Sweden and Norway | .......... | 425, 256 | 25 | .......... | .......... | 90, 866 | 425, 256 | 25 | 90, 866 |
| 12 | Portugal | .......... | 73, 195 | .......... | 11, 700 | 44, 304 | .......... | 73, 195 | 11, 700 | 44, 304 |
| | Totals of Class A | 3, 491, 811 | 84, 434, 595 | 2, 852, 540 | 62, 385, 741 | 4, 872, 388 | 88, 878, 746 | 87, 926, 406 | 65, 238, 281 | 93, 751, 134 |
| B | Within the yellow fever zone. | | | | | | | | | |
| 1 | Brazil | 4, 416, 766 | 6, 637 | 2, 160, 319 | .......... | 3. 366, 154 | .......... | 4, 423, 403 | 2, 160, 319 | 3, 366, 154 |
| 2 | Mexico | 1. 197, 080 | 707, 330 | 1, 052, 519 | 975, 502 | 996, 113 | 1, 113, 280 | 1, 904, 410 | 2, 028, 021 | 2, 109, 393 |
| 3 | Cuba | 3, 043, 697 | 189, 260 | 1, 035, 872 | 447, 236 | 1, 041, 605 | 262, 142 | 2, 232, 957 | 1, 483, 108 | 1, 303, 747 |
| 4 | Central American States | 81, 328 | 140, 310 | 99, 859 | 73, 314 | 135, 431 | 38, 395 | 221, 638 | 173, 173 | 173, 826 |
| 5 | British Honduras | 20, 536 | 63, 990 | 8, 514 | 48, 527 | 187, 698 | 120, 074 | 84, 526 | 57, 041 | 316, 772 |
| 6 | British West Indies | | | 10, 959 | 24, 015 | 10, 379 | 9, 038 | | 34, 974 | 19, 417 |
| 7 | French West Indies | .......... | .......... | .......... | .......... | 327 | .......... | .......... | .......... | 327 |
| 8 | United States of Colombia | .......... | 12, 222 | .......... | 10, 028 | .......... | 11, 344 | 12, 222 | 10, 028 | 11, 344 |
| 9 | Venezuela | 1, 980 | 4, 749 | .......... | .......... | .......... | .......... | 6, 729 | .......... | .......... |
| 10 | French, British, and other African ports | 57 | 30, 940 | 15 | 17, 250 | 874 | .......... | 30, 997 | 17, 265 | 874 |
| 11 | Azore, Cape Verde and Madeira Islands | .......... | .......... | .......... | .......... | 384 | .......... | .......... | .......... | 384 |
| | Totals of Class B | 7, 761, 444 | 1, 155, 438 | 4, 368, 057 | 1, 595, 872 | 5, 738, 965 | 1, 563, 273 | 8, 916, 882 | 5, 963, 929 | 7, 302, 238 |
| | Totals of all foreign countries | 11, 253, 255 | 85, 590, 036 | 7, 220, 597 | 63, 981, 613 | 10, 611, 353 | 90, 442, 019 | 96, 843, 288 | 71, 202, 210 | 101, 053, 372 |

| | | | | |
|---|---|---|---|---|
| The foreign commerce (coin and bullion included) of New Orleans and of the United States, compared. | New Orleans | 96, 843, 288 | 71, 202, 210 | 101, 295, 644 |
| | United States | 1, 210, 519, 390 | 1, 202, 708, 609 | 1, 613, 770, 633 |
| | | Tonnage. | Tonnage. | Tonngae. |
| The tonnage of vessels from foreign ports entering the port of New Orleans and all the ports of the United States, compared. | New Orleans | 718, 163 | 657, 780 | 769, 910 |
| | United States | 11, 530, 527 | 13, 772, 360 | 15, 240, 534 |

(1.)

## *FINAL REPORT UPON THE INSPECTION SERVICE OF THE NATIONAL BOARD OF HEALTH AT THE MISSISSIPPI RIVER QUARANTINE STATION, LOUISIANA, FROM JUNE 5 TO SEPTEMBER 30, 1881, INCLUSIVE.*

By G. FARRAR PATTON, M. D., *Inspector.*

QUARANTINE STATION,
*Mississippi River, Louisiana, September 30, 1881.*

Dr. STANFORD E. CHAILLÉ,
*Supervising Inspector National Board of Health:*

DEAR SIR: In reviewing the experience of the present quarantine season, it is gratifying to note the fact that up to this date, on which the inspection service of the National Board of Health terminates, not a single case of yellow fever has made its appearance at the Mississippi River quarantine station; a circumstance which cannot fail to delight sanitarians specially and the public generally. Having escaped thus far, it is not unreasonable to hope that within the short time yet to elapse before the date on which it is proposed to suspend quarantine, no case of this dreaded disease will appear.

It is also gratifying to me to reflect that my mission here, owing to a great extent to the courtesy of the State officers and their willingness to afford me every facility for observation, seems to have been a successful one as regards the objects chiefly aimed at by the National Board of Health. In this connection I shall briefly review those facts which seem to demonstrate the utility of the service in which I have been engaged, and the advantages likely to be derived from this service in the future, should it be decided to continue the same.

The chief aim of the National Board of Health in placing an inspector here, as set forth in Dr. T. J. Turner's letter of April 28, addressed to yourself, was to have a special representative of their own at the station upon whom they might depend for prompt and reliable information as to any case of yellow fever, or suspicious case, appearing at the station or in its vicinity, without which it would not be in the power of the National Board to notify the people at large of the first appearance of the disease in the Mississippi River, or to continue to assure them of its non-existence. In this particular my mission has been entirely successful, as I have had abundant facilities afforded me to make my observations.

During the entire summer only one case justifying suspicion has occurred—that of a young man on the Norwegian bark St. Olaaf, who became ill while this vessel was discharging coffee at the government wharf—but this case, within the first twenty-four hours, proved to be merely a simple fever. Other than this there have only been some cases of malarial fevers (see weekly and special reports) on vessels from the smaller Mexican and Central American ports, particularly from the Isthmus of Panama, but all of these were so distinctly characteristic as to afford no ground for suspicion.

A second object desired by the National Board of Health was to have its inspector remonstrate with the State officers in case any reasonable precautions were about to be neglected in their treatment of quarantine vessels, and to stand ready at all times to report to yourself and to the president of the State board of health any difference of opinion upon such matters or the refusal of the State officers to take any steps which might seem to the national inspector necessary for the public safety. Happily no occasion for the exercise of this prerogative has arisen, nor have I been called upon to extend my observations further than the station itself, the health of the surrounding country having been excellent. Besides attending to these leading objects of my mission, I have been enabled to compile from the records of the station—kindly placed at my disposal—yearly statistical tables "illustrating the maritime commerce of New Orleans by the Mississippi River" since June 1, 1855, the date at which these records begin, showing the number and class of vessels arriving each month, with the number of their crews and passengers, the countries they were from, an approximate estimate of the aggregate tonnage for each month, and the number of each class quarantined, besides furnishing you in special reports various items of information such as only could be supplied by one present at this station. As no official record had been kept of the length of time quarantined vessels had been detained at this station or of the sickness that had occurred on them up to July, 1880 (when Dr. Finney, soon after taking charge of the station, introduced a new and greatly improved system of keeping the records), it has not been possible to embody these items in all the tables; therefore I have prepared separate tables giving a résumé of quarantine work done at Mississippi River quarantine station for the four years of 1878-

-'79-'80-'81—having been enabled through the kindness of Mr. Thomas Flynn, telegraph operator at the station, to ascertain from his record book the day and hour of arrival and departure of every vessel passing up, from February 1, 1878, to the time when Dr. Finney's improved system of keeping the records was introduced. The items relating to sickness I have readily been able to supply, as I was on duty here as assistant resident physician from December 1, 1877, to May 20, 1880, since which time accurate notes have been kept by the State officers. These various tables, the credit of suggesting which is due entirely to yourself, I have the pleasure herewith of submitting, and hope you may not be disappointed in what you may have expected of them. I append to this report one table which presents a résumé of facts relating to the arrival of vessels at the Mississippi River quarantine station and the number detained there since June 1, 1855, besides eight additional tables for the years 1878-'79-'80-'81, in which the various items of information enumerated in the above paragraph are set forth in detail.

I regret that I have not been able to embody in the special table showing the work done this season exact figures as to the number of inspections made, as I have not observed any regularity in my visits to the shipping, this being almost impracticable, owing to the irregular hours at which vessels come and go, the state of the weather, and other circumstances which render it impossible to be as systematic about this work as a sanitary inspector whose work is on shore can be. Nor is it easy to arrive at any average as to the time occupied by my duties, since, in one sense, I have been nearly always on duty, having to be in readiness to drop everything and start upon the arrival of a quarantined vessel, or when one was ready to leave, or when fumigation was about to be begun, or when a certain stage in the handling of a cargo was reached—it sometimes being before sunrise when these visits had to be made, and sometimes before midnight. Even the apparently social side of my relations with the quarantine officers and with the officers of vessels has not been without a certain bearing upon my official duties, so that the round of these duties, though not arduous, has been almost continuous.

As regards the probable utility of this special inspection service in the future, I need only remark that, as the people at large become every day more interested in matters affecting sanitation and the prevention of pestilence by means of national quarantine regulations, it will surely be expected of the National Board of Health, upon whom the general public rely for protection, to station a representative at this point, where danger is most to be expected. Aside from this view of the matter, it might happen that under less vigorous administration proper precautions would be neglected, or laxity of discipline allowed at the station, in which case it would become necessary for the national inspector to remonstrate. In short, in any case where in the future the quarantine officers might be disposed toward negligence or indifference, the presence of such an inspector could hardly fail to stimulate them to greater vigilance and more rigid enforcement of quarantine rules than would otherwise be the case.

Further than this, the national inspector at this station has an admirable opportunity to inquire into the sanitary regulations of foreign countries, and to learn of fraudulent practices in vogue abroad, as, for instance, the issuing of false bills of health and certificates, from giving credence to which danger might arise. I have had occasion this summer to forward you a statement in writing from an American ship-master, charging a physician, countenanced, as was alleged, by the United States consular establishment in Rio de Janeiro, with issuing certificates of inspection and disinfection, for a money consideration, actually without going near the vessel.[*]

The exact figures showing the expense attached to the practical working of the service this season, and what may be reasonably expected for future years, will be found in the following statement:

Expenses of every kind for inspection service at Mississippi quarantine station for less than four months of 1881, $1,778.48.

Estimate of all necessary expenses of same service for five months of 1882, $2,436.

Owing to the service not having begun until June 5 this season, and to the fact that the steam-launch was not supplied until July 5, the expense involved has been considerably less than would be the case were the service to be put in full operation at the beginning of any subsequent quarantine season.

As the performance of his duties requires the inspector of the National Board of Health at this station to be so constantly on the river, it is, of course, indispensable that he should have a boat at his command; and as the expense of keeping a steam-launch is so little more than that required for a row-boat—the difference being about $150 or $200 a season, while the advantages of the former as regards speed, comfort, and ability to stem the strong current of the Mississippi are so obvious—I would advise the use of the steam-launch being continued, particularly as the National Board already owns a suitable launch. In this connection I have submitted a separate report upon some slight changes in the lookout that seem to me to be called for.

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[*] It subsequently transpired that this charge was unfounded.

As you have requested me to do so, I shall next notice what may be considered as defects in the quarantine system administered at this station, and shall suggest certain measures which occur to me as being calculated to remedy these defects. Attention has been called to the absence of any organized police force at this station. On this point I am far from being convinced that such a force is necessary. If supplied it might be a source of satisfaction, but during a residence of three years at this station I have never seen any evidence that such a force is required in the interest of sanitation; first, because the country around the station is but thinly populated, and the inhabitants, for the most part simple-minded people—fishermen and negroes engaged in rice culture—have the greatest respect for quarantine regulations, so that to keep them in restraint nothing further would be necessary than to have it generally known that communication with people belonging to quarantined vessels was forbidden; and secondly, because there is never any willful attempt on the part of those belonging to quarantined vessels to violate any rule which the resident physician may see fit to establish, since sea-going people, almost without exception, stand in wholesome dread of the arbitrary power which they believe quarantine officers possess.

My ideas of what is required are as follows: Let the legislature create the resident physician an *ex-officio* justice of the peace, limiting his jurisdiction to offenses connected with violations of quarantine laws, and to general offenses committed at the station and on the vessels detained there, and authorizing him to appoint one of his boatmen, as, for instance, the coxswain, a constable. This arrangement would answer every purpose, and besides placing the power where it could be promptly and judiciously brought to bear, it would be economical, and would obviate the employment of additional men.

A more serious difficulty is that under the existing law the parish police jury gives the public the right of way through the quarantine grounds, thus rendering it impossible to prevent people living outside from entering and passing through.

During the summer and autumn, when quarantine regulations ought to be most strictly enforced, dozens of people pass through the grounds daily, these being for the most part laborers from the rice fields. On Sundays, owing to the social and religious tendencies of the colored population, this traffic is greatly increased. The remedy for this would be for the legislature to make the quarantine grounds a special reservation, forbidding any thoroughfare through the same, and requring the public road to pass in the rear of the station, where there is an abundance of room. The same law should direct the land entrances to the station to be guarded by high gates, which could be kept locked during the prevalence of infectious sickness at the station. With these precautions undue intrusion could be prevented.

As regards preventing improper intercourse between quarantined vessels and the shore, I think the existing rules are adequate for all contingencies. It would be better, however, for the State officers to supply vessels detained at the station, not with a copy of the various laws and amendments printed in English, as furnished at present, but with a clear and concise set of rules setting forth briefly and unmistakably that such and such privileges are allowed and certain others therein specified forbidden. These ought to be printed in at least six languages, and a sufficient number of copies ought to be distributed on each vessel to instruct the whole ship's company.

A serious trouble, and one of the most difficult to remedy, is the possibility of pilots and others from infected vessels landing at Port Eads or Pilottown and communicating infection to the people there, or even of going directly to New Orleans by the packet boats. Here again legislative action is called for. A severe penalty, (with a reward to the informer) should be inflicted upon any pilot or other person landing within a given period after having boarded an infected vessel, and the existing law, forbidding steamboats and tow-boats to receive as a passenger any person liable to quarantine, might be amended so as to afford a greater degree of protection. The plan of stationing an inspector at Port Eads is admirable, as practiced by the State board of health the past two seasons, but even here there is room for improvement, as it is difficult for one officer to watch all the sea entrances to the river. But the greatest difficulty to be overcome is that of dealing with the cargoes of presumably infected vessels, and particularly with cargoes of coffee from Rio de Janeiro. It is obvious that mere detention of a cargo can have no effect in destroying germs of disease therein contained, so that if a plan can be devised and put in operation by which the sanitary measures instituted for this object may be so perfected as to permit the almost immediate forwarding of such cargoes to their destination, a great advantage to commerce would be gained. Under the system at present in force at this station, which is probably the best that circumstances will allow, cargoes of coffee are discharged and the sacks heaped up in the government warehouse, where they are fumigated *en masse.*

While the work of removing and returning the cargo is going on, the vessel itself is fumigated every night, so that it may be said, as far as intensity of fumigation goes, that there is nothing left to be desired. But it is evident that in fumigating a warehouse full of coffee in one mass, the sulphur fumes cannot possibly penetrate between the sacks, so that, supposing any "germs" attached to the sacks to be equally distributed over their surfaces, only those germs occupying the exposed parts of the sacks will undergo the destructive action of the sulphurous-acid gas. In a sanitary point of view, this alone constitutes a very serious objection to warehouse fumigation as at present carried on. But from a commercial standpoint, there are objections which deserve consideration. Inasmuch as it is not desirable to have the crew of a vessel expose themselves by working in the presumably infected atmosphere of the hold, it is necessary to employ a force of acclimated laborers and a stevedore's foreman, thus making the expense for this item alone very considerable.*

Besides this, the distance over which the coffee has to be "trucked" varies from 300 to 500 feet each way, and when it is finally returned on board the vessel it has been handled five times: 1, hoisted out of the hold to the truck; 2, from the truck to the pile in the warehouse; 3, back to the truck; 4, hoisted on board; 5, stowed away.

Now, it seems to me that the true plan for dealing with such cargoes is the following: Let the coffee be hoisted directly into a barge, moored alongside the vessel at anchor in the stream, thus preventing any opportunity for those belonging to the vessel to walk ashore; there fumigated in detail by some plan which would allow the sulphur fumes to reach every portion of the surface of each separate sack, and immediately stowed away in the hold of the barge. As soon as the work shall have been completed, let the barge be towed to New Orleans, thus delivering the coffee promptly to the consignees, and leaving the vessel to remain as long as might be considered necessary at the quarantine station. This would render fumigation thorough and effective, would avoid the "trucking" of the cargo a long distance, would insure its prompt delivery in New Orleans, and would leave the vessel empty and ready for the most severe sanitary measures that might be indicated.

There would certainly be some practical difficulties to contend with in organizing such a barge service, and with a view toward aiding in the solution of these difficulties, I herewith submit diagrams giving an idea of the plan of such a barge as I conceive would be adapted to the purpose. The notes attached to the diagrams will serve to explain the plan proposed.

As shown in figure 2, there are two fumigating chambers at either end, making four in all. Along the wall, on either side of each chamber, are four rows of ring bolts, serving as points of attachment for the movable ladders. The proposed plan of using the barge is as follows:

Moor the barge alongside of the loaded vessel at anchor. By means of the derricks, worked by the hoisting engines shown at either end, hoist the sacks into the barge and place them as shown in figure 2 on the ladders, placing the latter in position one after another as they become full, working from the middle of the barge toward either end, and using a strong step-ladder to reach the upper tiers. When working only one derrick, but one pair of fumigating chambers will be used, filling the right-hand one while the left is being fumigated, and so on. When working both derricks, the right-hand chamber on one end and the left-hand one on the other must be filled simultaneously in order to balance the barge. Beside the hoisting apparatus, each engine has attached to it a blower and a powerful force-pump. The use of the former is to drive a current of air through each fumigating chamber while it is being filled, so as to ventilate the coffee before fumigating it. During fumigation the blast is shut off, and when the fumigation is completed, the hatches ($x$) ($x$) (figure 1) in the roof being opened, the blast is turned on, and serves to drive the suphuric-acid gas rapidly away. On removing the sacks or other articles from the fumigating chambers, they are run down a chute into the hold and stowed away, not to be disturbed again until finally discharged. The force-pump is for use in case of fire, and for washing out the holds of vessels.

The very first question connected with the adoption of the proposed barge service, granting that it promises all that can be claimed for it, is, who is to supply the barges, and how are the running expenses of the system to be met? My views on this subject are as follows:

In the first place, it is not to be expected that the State board of health or the legislature of Louisiana, with their present limited pecuniary resources, could be relied upon to furnish the money necessary to carry out such a scheme. I think this will be admitted without argument. Next follows the question as to whether this barge service promises to be of sufficient importance to justify the National Board of Health in applying to Congress for whatever funds might be required to put it in operation.

Now, inasmuch as sulphur fumigation is absolutely the only means upon which we have to depend for the purification of presumably infected cargoes, it stands to reason that any plan which will beyond all doubt render this fumigation thorough, is to be

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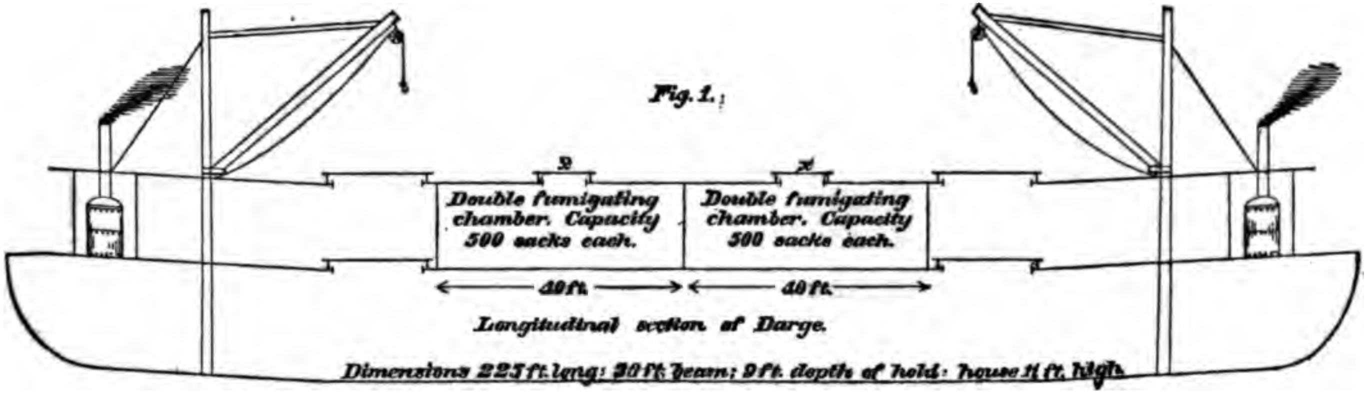
* On small barks and brigs of 400 or 500 tons, from twenty to thirty men, at $2.25 a day, and a foreman at $5 a day, have been employed this summer. The time required to handle the cargoes of such vessels is from six to eight days, or longer, if the weather should be unfavorable.

DIAGRAM SHOWING PLAN OF BARGE FOR FUMIGATING COFFEE AND OTHER CARGOES.

*Cost, as per estimate of a practical boat-builder, $13,000.*

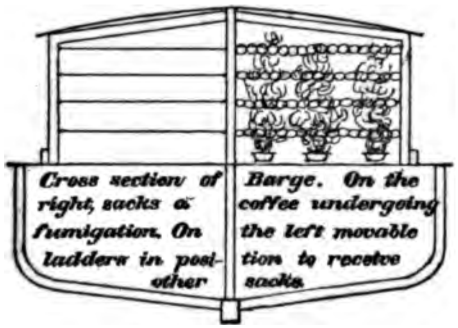
Fig. 1.


D
Double fumigating chamber. Capacity 500 sacks each.
Double fumigating chamber. Capacity 500 sacks each.
40 ft.
40 ft.

*Longitudinal section of Barge.*

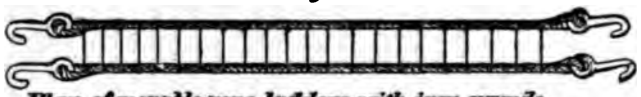
*Dimensions 225 ft. long; 30 ft. beam; 9 ft. depth of hold; house 11 ft. high.*

Fig. 2.



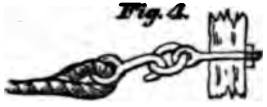
*Cross section of Barge. On the right, sacks of coffee undergoing fumigation. On the left movable ladders in position to receive other sacks.*

Fig. 3.



*Plan of movable rope ladders with iron rounds to be stretched across the fumigation chambers to support sacks of coffees or other cargo. When not in use these ladders to be taken down and stowed away.*

Fig. 4.



*Showing hook and ring bolt for attaching the movable ladders.*

preferred to the plan now in use, under which it is impossible for the purifying gas to penetrate to every portion of the mass of cargo under treatment.

It may be said that at best we are not certain that the most thorough fumigation is to be relied upon—though individually I have great confidence in it—but with our present knowledge it is unquestionably incumbent upon us to render the process, such as it is, as thorough as possible.

In an issue of this kind it seems reasonable that the National Board of Health—standing in the relation of guardian and protector of the nation's health, and knowing that no expenditure of the people's money will be considered excessive if thereby any greater security from an invasion of yellow fever is promised—should be prepared to assist in supplying any appliances that may be needed to perfect the processes upon which we have to depend for security, for it is evident that without help from this quarter the matter will be allowed to go on as it is, and under an administration less vigorous than the present one, even the system now in use might degenerate.

The mere question of the apparent inconsistency of the National Board offering to supply the State board of Louisiana with expensive improvements at the quarantine station, which the State board has not asked for and may not desire, has nothing to do with the moral side of the issue involved. If it be proven that such improvements would be beneficial to the service and conducive to the preservation of the public health, and that otherwise they will not be furnished, it seems to me that the National Board can have no higher duty than to induce the general government to supply them. The mouth of the Mississippi River is the great thoroughfare through which yellow fever is most likely to enter, and New Orleans is the city where the greatest precaution needs to be observed. Therefore, as compared with the necessity for perfecting every means of keeping yellow fever away from New Orleans, all other objects that might claim the attention of a national board of health would seem to sink into insignificance.

Suppose that the State board of health does not see the necessity for such improvements, is the duty of the national board to the people of the Mississippi Valley, to the "Great Southwest," and to the nation at large any the less imperative?

To use an illustration that will be appreciated in the State: If a planter should see the levee of an impecunious neighbor about to break, threatening devastation to the whole neighborhood, would he hesitate to resort to the most ready means of averting the danger, regardless of any apparent indifference on that neighbor's part?

Show the State board the advantages of the proposed system, offer to defray the expense of putting it into operation and keeping it up, and they can hardly refuse to avail themselves of it.

To complete the plan which I propose, a tug-boat, either owned or chartered by the government, ought to be stationed here for the purpose of moving the barges, or even of towing them to New Orleans, in case the private tow-boat corporations were disposed to demand exorbitant rates. If it even should be decided to send an infected vessel from the mouth of the river to Ship Island, the gratuitous services of a government tug-boat, offered in such an emergency, would remove the two greatest practical difficulties in the way, viz: the delay to the vessel in reaching Ship Island, and, on the other hand, the expense to the owners of having her towed there and back. Here again it may be argued that the government has no right to interfere in the towing business, but I claim that in a matter involving any issue of vital interest to the whole country, all ordinary motives of policy and all theories as to what a government ought not to do should be ignored. "*Salus populi suprema lex esto.*" And since we can neither prevent vessels infected with yellow fever, nor vessels laden with presumably infected cargoes, from coming to our shores, and since the expense of treating such vessels according to thorough methods is likely to be too great for individuals to bear, while to a nation like the United States the expense would be a mere bagatelle, let us calmly accept the situation and pay the bill for the preservation of our own health without grumbling.*

The first cost of putting the proposed barge system into operation would be considerable, probably between $40,000 and $50,000, and after that an annual expenditure of about $5,000 would suffice to carry it on. Among other things, it would be necessary to keep a small open barge at the station to be used in carrying ballast to vessels whose cargo had been discharged. The supply of ballast could be readily replenished from other vessels in quarantine.

In conclusion, I would urge, in pursuance of the policy which I have above advocated, of accepting the inevitable and of making the best of circumstances beyond our control, that the National Board of Health cannot do better for the present than to use what means and influence it can bring to bear in perfecting the existing quar-

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*** It would be well, among other measures, for the government to notify its consuls in all the principal cities of quarantined districts, early in each season, of the measures likely to be enforced at the different quarantine stations of the United States, so that masters of vessels sailing for any one of our ports may know exactly what they have to expect.**

antine stations of this State, and in particular the Mississippi River station, of course without attempting to interfere in the management of the stations; the idea being to give every possible assistance and to leave the execution of the work itself entirely in the hands of the State officials.

The facts are before us that the Mississippi River quarantine station is located in a position open to some serious objections, and that without due vigilance infection may be smuggled through; but what is to be done?

The location of this station, and its control by a local board of health extremely sensitive on the subject of national interference on established facts, so that it only remains to the United States Government, reversing the order ascribed to Providence, to help those who will *not* help themselves—which can only be done in this instance by co-operating with them—allowing them undisputed possession of the field, and doing its best to aid the State of Louisiana in perfecting the means which it employs and upon which the people at large, whether they like it or not, have to depend for protection against the invasion of yellow fever.

I am aware that some of my views may be regarded as those of an enthusiast, hoping for impossible things, and that the execution of the plans I propose may appear to offer serious difficulties; but I am sustained by the reflection that all who would aid in any work of reform must expect to encounter opposition and difficulties, and these views, such as they are, are the honest convictions of one who has served at least an apprenticeship in practical quarantine work.

With the hope that it may not remain for any dearly-bought experience to demonstrate the utility of such suggestions, I have the honor to remain,

Yours, very respectfully,

J. FARRAR PATTON, M. D.,
*Inspector.*

*Resumé of data relating to the arrival of vessels, and the number detained at the Mississippi River quarantine station, Louisiana, since its establishment, June* 1, 1855.

[Compiled by G. Farrar Patton, M. D., inspector National Board of Health.]

Mississippi River blockaded by United States Government May 28, 1861. Vessels began to arrive again June 19, 1862.

| Year. | Steam vessels. | Sailing vessels. | Total number arriving. | Total number quarantined. | Year. | Steam vessels. | Sailing vessels. | Total number arriving. | Total number quarantined. |
|---|---|---|---|---|---|---|---|---|---|
| 1855 | 132 | 850 | 982 | 4 | 1868 | 572 | 682 | 1,254 | 3 |
| 1856 | 214 | 1,594 | 1,808 | 7 | 1869 | 581 | 817 | 1,398 | 44 |
| 1857 | 243 | 1,605 | 1,848 | 66 | 1870 | 533 | 820 | 1,353 | 50 |
| 1858 | 275 | 1,608 | 1,883 | 51 | 1871 | 540 | 987 | 1,527 | 40 |
| 1859 | 304 | 1,538 | 1,842 | 90 | 1872 | 411 | 795 | 1,206 | 26 |
| 1860 | 321 | 1,513 | 1,834 | 58 | 1873 | 378 | 711 | 1,089 | 57 |
| 1861 | 140 | 665 | 805 | 1 | 1874 | 449 | 818 | 1,267 | 66 |
| 1862 | 132 | 484 | 616 | 49 | 1875 | 296 | 706 | 902 | 102 |
| 1863 | 350 | 643 | 993 | 63 | 1876 | 311 | 840 | 1,151 | 130 |
| 1864 | 581 | 893 | 1,474 | 91 | 1877 | 366 | 625 | 901 | 136 |
| 1865 | 796 | 992 | 1,788 | 128 | 1878 | 396 | 664 | 1,060 | 181 |
| 1866 | 746 | 888 | 1,634 | 165 | 1879 | 466 | 576 | 1,042 | 168 |
| 1867 | 617 | 799 | 1,416 | 68 | 1880 | 614 | 657 | 1,271 | 150 |

## *FINAL REPORT FOR THE FIVE MONTHS FROM MAY* 1 *TO SEPTEMBER* 30, 1881, *INCLUSIVE.*

RIVER INSPECTION SERVICE, NATIONAL BOARD OF HEALTH.

NEW ORLEANS, LA., *October* 1, 1881.

DR. STANFORD E. CHAILLÉ,
*Supervising Inspector:*

DEAR SIR: The River inspection service of the National Board of Health has for the past five months been carried on in New Orleans under your direction by ourselves.

We have received as our compensation the sum of $150 each per month; the amount $1,500 was the total expenditure of the service conducted by us. The average daily time required for the performance of our duties has been about four hours each.

Owing to the fact that several boats frequently leave about the same hour two inspectors are necessary, in order that boats may receive their inspection certificates as nearly as possible at the time of departure. Were it not for this fact, one inspector might accomplish the work. Sanitary policemen are not necessary except when yellow fever exists and disinfection is essential.

In addition to the inspection of boats we have given considerable time daily to obtaining, 1st, the daily record of entrances at the custom-house, of vessels; 2d, the daily mortuary report from the State board of health.

The following table gives the entrances at the custom-house for the five months May 1, to September 30, 1881, inclusive:

TABLE No. 1.—*Statement of vessels arriving at New Orleans (May 1 to September 30) from infected and non-infected ports.*

| Classification of vessels. | Steam vessels. | Tonnage. | Sail vessels. | Tonnage. | Cargo. | Ballast. | Non-infected ports. | Infected ports. | Total vessels. | Total tonnage. |
|---|---|---|---|---|---|---|---|---|---|---|
| Foreign vessels from foreign ports | 92 | 163, 126 | 81 | 48, 752 | 118 | 55 | 123 | 50 | 173 | 211, 878 |
| American vessels from foreign ports | 29 | 25, 253 | 42 | 13, 810 | 65 | 6 | 46 | 25 | 71 | 39, 063 |
| Coastwise vessels | 74 | 138, 780 | 39 | 16, 235 | (*) | (*) | 113 | ...... | 113 | 155, 015 |
| Total | 195 | 327, 159 | 162 | 78, 797 | 183 | 61 | 282 | 75 | 357 | 405, 956 |

*Not given.

In the above table the following have, at the Mississippi quarantine station, and therefore by us, been considered infected ports, viz: Not only Rio de Janeiro, Vera Cruz, the island of St. Thomas, and the Cuban ports of Havana, Cienfuegos, Cardenas, Santiago de Cuba, Sagua la Grande, and Matanzas, but also Tuxpan, Tampico, Colon, Minatitlan, Progresso, Laguna, and Coatzacoalcos, although no yellow fever, it is believed, existed in the latter list.

TABLE No. 2.—*Number &c., of river craft inspected at New Orleans from May 1 to September 30, 1881, inclusive.*

| Months. | Steamboats. | Tonnage. | Officers, crews, and passengers approximated. | Barges for grain inspected. | Tonnage estimated at 1,500 per barge. | Ice and hay barges. | Open coal flats not requiring inspection. | Survey boats, &c., inspected. | Barges requiring inspection but not inspected. | Boats departing without notifying inspector and not inspected. |
|---|---|---|---|---|---|---|---|---|---|---|
| May | 53 | 48, 376. 83 | 4, 715 | 39 | 58, 550 | 8 | 18 | 2 | 3 | 1 |
| June | 43 | 36, 298. 23 | 3, 745 | 55 | 82, 500 | 1 | 6 | 2 | ...... | ...... |
| July | 48 | 34, 659. 82 | 3, 745 | 48 | 72, 000 | 3 | 25 | 1 | ...... | 2 |
| August | 30 | 26, 019. 33 | 2, 562 | 25 | 36, 000 | .... | ...... | .... | ...... | 2 |
| September | 29 | 34, 320. 87 | 2, 728 | 29 | 43, 500 | .... | ...... | .... | 6 | 3 |
| Total | 203 | 179, 675. 08 | 17, 495 | 196 | 292, 500 | 12 | 49 | 5 | 9 | 8 |

The total number of inspections, 203 steamboats and 201 barges, &c., is small as compared with last year. This has been owing to several causes; the low stage of water in the Ohio, Mississippi, and Red Rivers, and the non-existence of the Bayou Sara station established last year for boats entering Red River.

In the Shreveport Times of July 13 was published an ordinance of the city council of Shreveport requiring all boats coming from New Orleans to have a certificate of inspection from an inspector of the National Board of Health.

Only four boats were inspected in this trade, as no other left for Shreveport on account of the low state of water in Red River. With these exceptions, no boats stopping short of Vicksburg and none going below New Orleans have been inspected, since no orders were issued therefor.

Referring to the table, you will observe that only eight boats and nine barges, which should have been inspected, left without being inspected. These boats, with one exception, having been here for some days, and not notifying us of the time of their departure, we had no means of knowing when they were to leave. The exception was the towboat Port Eads, Capt. Nelson Davis, with six barges, bound for Saint Louis, September 27. She left one hour sooner than the time stated by the agent to the inspector. She was, however, at this time seen backing out, and boarded by the inspector, but the captain refused to wait for an inspection. This is the only instance of this kind. The reason the other three barges were not inspected was because in the several instances the barges were distant from the towboat, and we did not know until near the time of departure that they would compose part of the tow.

As regards cargoes, there were no restrictions till July 10. On this date the Memphis ordinance of June 30 prohibiting the landing at that place of any boat having on board "any article of the class commonly known as junk stores, such as rags, paper stock, old rope, second-hand clothing, bedding, and upholstered furniture," went into effect.

From May 1 to July 10 there were shipped from New Orleans by steamboat about 450 bales of old rope and paper stock. Estimating each bale at 600 pounds and the freight at fifteen cents per hundred weight, we get $405, which would approximate the insignificant loss to the steamboat trade for nearly two months and a half, had these articles been excluded from the cargoes, as would have been done had yellow fever appeared.

The number of *persons* as set down in the table represents only the best attainable approximation to the actual number of crews and passengers.

In concluding this report we would present for your consideration some remarks tending to show the utility of this service, and a few suggestions calculated to remedy certain defects and to facilitate its operation.

From the stand-point of preventive medicines, we believe this service has secured an improved sanitary condition of steamboats and barges, and has brought about among shippers and common carriers a heightened sense of public health responsibility; at the same time it has afforded more efficient safeguard against the spread of disease. Economically, it has proved to the steamboat interest, and to the interests of commerce generally, the best system that could have been devised.

In times when no yellow fever exists the inspection at New Orleans of boats has reference chiefly to the cleanliness of the boat and the character of the cargo. The enumeration of the persons on board might well be omitted from the boat's certificate of inspection, since experience has taught us that in nearly every instance this is at best only an indifferent approximation, as many register after the boat has left, and there is no way of making them register sooner.

But when yellow fever prevails, this enumeration becomes important. In this case no person should be allowed to take passage except he shows a proper certificate, procured, if possible, from an inspector on land, as this would obviate the great difficulty of issuing a large number of personal certificates at the time of departure of the boat. The number of personal certificates would then correspond with the number expressed on the boat's certificate. Those boats which might refuse to enforce this requirement should be refused the certificate.

We concur in your view that every medical man employed as an inspector should, so far as practicable, gain the experience necessary to enable him to perform the work of any other inspector, especially so far as the river and the railroad services are concerned, so that in case of necessity any one inspector might take the place of any other and efficiently discharge his duties.

Very respectfully,

F. W. PARHAM, M. D.,
P. B. McCUTCHON, M. D.,
*Inspectors of the National Board of Health for the river service at New Orleans.*

## (3.)

## *REPORT OF INSPECTIONS AT CHICAGO, SAINT LOUIS AND NEW ORLEANS RAILROAD, FROM AUGUST 17 (DATE OF COMMENCEMENT OF SERVICE) TO SEPTEMBER 30, INCLUSIVE.*

NATIONAL BOARD OF HEALTH, RAILROAD INSPECTION SERVICE,
*New Orleans, October* 1, 1881.

| | Last fifteen days of August. | September. | Total. |
|---|---|---|---|
| Number loaded cars inspected | 561 | 1,288 | 1,849 |
| Number empty cars inspected | 467 | 1,162 | 1,629 |
| Number freight trains inspected | 38 | 75 | 113 |
| Number persons thereon | 190 | 375 | 565 |
| Number passengers arriving.... passengers and passenger trains were not | 1,883 | 4,191 | 6,074 |
| Number passengers departing.. inspected. | 1,925 | 3,489 | 5,414 |
| Number car-loads fruit (not including small shipments) | 20 | 17 | 37 |
| Number trains carrying same | 3 | 8 | 11 |
| Number bales rags and paper-stock | 192 | 81 | 273 |
| Number cars containing same | 14 | 10 | 24 |
| Number trains carrying same | 14 | 10 | 24 |
| Total number freight cars leaving New Orleans | 1,028 | 2,450 | 3,478 |

Rags and paper-stock enumerated above were carried through in sealed cars to points north of the Ohio River.

The average daily time consumed in making inspections was four hours.

My duties were confined to the freight depot. In case of necessity arising for the inspection of passenger trains and passengers, an additional inspector would be required, inasmuch as the passenger and freight depots are not connected and are a long distance from each other, thereby making it an impossibility for one inspector to perform both duties.

The utility of the inspection of freight is demonstrated by the fact that in the shipment of rags, paper-stock, and such like dangerous material, it was not allowed to be transferred from car to car south of the Ohio River, and in case of the occurrence in this city of yellow fever their shipment could be prevented altogether. Also in maintaining a proper sanitary condition of the cars, depots, yards, and surroundings.

I would recommend that the National Board of Health use its influence with railroad companies to prevent, as far as possible, the shipment during the summer months of such materials as rags, glue-stock, green hides, and all decomposing animal and vegetable matter, and that authority (now lacking) be given inspectors to stop the same.

The expense of the service this year was borne by the railroad company, which offered every facility for the proper performance of the duties of the inspector.

Daily certificates of inspection were issued to all out-going trains.

Very respectfully,

L. F. SALOMON, M. D.,
*Inspector.*

Dr. S. E. CHAILLÉ,
*Supervising Inspector, National Board of Health.*

## *REPORT OF INSPECTIONS FROM AUGUST 17, DATE OF COMMENCEMENT OF SERVICE, TO SEPTEMBER 30, INCLUSIVE.*

### LOUISVILLE AND NASHVILLE RAILROAD.

NATIONAL BOARD OF HEALTH, RAILROAD INSPECTION SERVICE,
*New Orleans, October* 1, 1881.

| | August, 15 days. | September. | Total. |
|---|---|---|---|
| **Number of loaded freight cars inspected** | **476** | **909** | **1, 385** |
| **Number empty freight cars inspected** | **332** | **849** | **1, 181** |
| **Number freight trains inspected** | **29** | **65** | **94** |
| **Number persons thereon** | **165** | **210** | **375** |
| **Number persons on passenger trains arriving** | **15, 935** | **9, 038** | **24, 973** |
| **Number persons on passenger trains departing** | **16, 884** | **7, 326** | **24, 210** |
| **Number car-loads fruit (not including small shipments)** | ........ | **2** | **2** |
| **Number bales rags and paper-stock** | **744** | **438** | **1, 182** |
| **Number cars containing same** | **11** | **23** | **34** |
| **Number trains carrying same** | **3** | **8** | **11** |
| **Total number freight cars leaving New Orleans** | **808** | **1, 758** | **3, 566** |

**Rags and paper-stock enumerated above were carried through in sealed cars to points north of the Ohio River.**

**The average time required daily for these inspections is not more than four hours, owing to the favorable arrangement of the depot and the manner of loading the cars.**

**As to the facts bearing on the utility of said service, its practical application during a season in which yellow fever prevailed in the city would be necessary to thoroughly demonstrate the value of the service. It is certain, however, that two results are accomplished which are of practical importance:**

**1st. The confidence established along the line of travel by the assurance that no goods known to be infected will be shipped.**

**2d. The restriction which is placed on the shipping or moving of objectionable articles, such as rags, second-hand clothing, old bedding, fruits, &c., during the heat of summer.**

**An experience of two summers as inspector of this depot convinces me that the railroad officials are anxious and willing to aid in the enforcement of a judicious quarantine system, and while it is distinctly understood that in the proposed shipment of any prohibited article the National Board of Health have no authority to stop said shipment, yet practically it amounts to the same thing, as in every such case they would refuse to ship it unless I would issue the usual certificate.**

**As to the defects of said service, I am disposed to believe that as it exists it is capable of accomplishing the objects desired. It must be remembered I refer only to the inspection at the freight depot. In case of a necessity for inspection of passenger trains an additional inspector would be required, owing to the two depots being located some distance from each other.**

**The expense incident upon this inspection has been met by the Louisville and Nashville Railroad Company.**

**Respectfully submitted.**

J. M. WATKINS, M. D.,
*Inspector National Board of Health.*

Dr. S. E. CHAILLÉ,
*Supervising Inspector, National Board of Health.*

## APPENDIX 12.

## CONFERENCE ON SMALL-POX.

The State board of health of Illinois called a conference of delegates from State and municipal boards of health to meet in Chicago, June 29, to consider and adopt measures for the united action of health authorities to prevent the introduction of small-pox into the United States, and its spread from one State into another. Delegates were in attendance from the State boards of Illinois, Michigan, Iowa, Wisconsin, Indiana, Minnesota, Maryland, and New York; from the National Board of Health, and from the municipal boards of Chicago, Milwaukee, Buffalo, Baltimore. **JOHN M. GREGORY**, LL. D., president of the State board of health of Illinois, was called to the chair, and Dr. **HENRY B. BAKER**, secretary of the State board of health of Michigan, was appointed secretary. The conference continued in session two days, and closed its proceedings by adopting the following report and resolutions:

The constantly recurring outbreaks of small-pox in various parts of the United States during the past few months and the widespread and fatal prevalence of that disease in many localities demand the most serious consideration of the health authorities of this country. In our opinion this conference should use its utmost power to unite all of the health authorities of the United States in a well-organized plan, not only of stamping out small-pox where it at present exists, but of preventing its farther introduction into the United States and its spread from one State into another. For two or three years prior to 1879 small-pox was almost unknown in the United States; certainly, scarcely a death was reported. The result of a long-continued immunity from this disease is great laxity in regard to vaccination. Large numbers of children born during such periods are allowed to remain unvaccinated in every community. Hence, when small-pox appears after such intervals of immunity from the disease, it spreads with far greater virulence than when vaccination is enforced by the fear which the presence of small-pox creates. In 1879 there were a few deaths by that disease in New York (25) and in San Antonio, Tex. (125), but the country at large enjoyed a remarkable immunity from that affection. The cases in 1879 in New York occurred among unprotected foreigners, and those in San Antonio were unprotected New Mexicans. But during 1879 small-pox began to be more than usually prevalent in European seaports and in Canada. Much uneasiness was felt by many of the most vigilant sanitary officers in different parts of the country lest the infection should be brought to this country, especially from the neighboring Province of Canada, particularly at Montreal. In several instances local outbreaks of the disease occurred along the Canada frontier, owing to the importation of the infection through immigrants. Towards the close of the year 1879 there were evidences of a wider distribution of small-pox than could be accounted for by importation from Canada. It appeared in New York, Philadelphia, Chicago, the District of Columbia, and other cities. During the year 1880 these outbreaks became more general, and were most marked in the Western and Northwestern States, while in the larger Eastern cities it prevailed with a constantly increasing tendency to become epidemic. The present year, 1881, opened with a wide distribution of the disease, and frequent local epidemics of great severity.

From reliable sources it is known that small-pox prevails to an unusual extent in many of the large cities of the North and West, and that violent and fatal epidemics of this disease are of frequent occurrence in small towns and in small communities of many States.

If, now, we inquire into the cause of this diffusion of small-pox throughout the country, we shall find that immigration is at least an important factor.

*First.*—It must be remembered that small-pox became epidemic or certainly unusually prevalent in foreign seaport towns and in Canada in 1878, 1879, and 1880, and is at present the prevailing epidemic disease in these towns. From the following table it appears that the tide of immigration to this country from Europe began to rise in 1879, and in 1880 reached proportions hitherto unprecedented in the history of immigration to this country. And still the tide is rising, as appears from the following late reports of the Chief of the Bureau of Statistics at Washington, viz: for nine months ended March 31, 1880, 214,596; for the same period in 1881, 357,396. The total increase in the number of immigrants during the last nine months is 142,800. From still later reports we learn that the arrival of immigrants at the principal ports of the United States is yet on the increase. Indeed, it is no unusual occurrence to witness the arrival of from 6,000 to 8,000 immigrants at the port of New York in a single day.

*Second.*—It must be noticed that the immigrants are largely from Germany, England, Wales, Ireland, Scotland, and the Dominion of Canada, countries in which small-pox has been, and still is, unusually prevalent. The number of immigrants arrived during the eleven months ended May 31, 1881, was as follows: From Germany, 175,306; Dominion of Canada, 110,611; England and Wales, 57,861; Ireland, 61,796; Scotland, 12,628; China, 7,443; and from all other countries, 138,649. Total, 564,294.

*Third.*—The number of cases of small-pox arriving on immigrant ships at the ports of the United States is unusually large, as reported by the health officers of the several ports of arrival. With rare exceptions the sick immigrant is not effectually isolated from the steerage passengers. The hospital quarters are usually amidships, with no adequate means of seclusion nor independent ventilation. As a consequence 1,000 to 1,600 persons are more or less directly exposed to the contagion and infection; nor is vaccination of the passengers practiced or even attempted at sea, so that when the ship reaches its destination it may have on board many persons who are thoroughly inoculated with the contagion, though as yet apparently perfectly well.

*Fourth.*—Another important fact is the rapidity of ocean transit, which must be taken into consideration in estimating the influences of immigration on the importation and dissemination of small-pox. While the incubation period of small-pox is fourteen days, eight to twelve days is the average period of the voyage of the immigrant vessel arriving at New York, where the greater number of immigrants land. Now, it is a well ascertained fact that the emigrants reach the ports of embarkation commonly several days before the sailing of the ship. During this interval the emigrant families take quarters in the low lodging houses about the docks and wharves in which small-pox is now very prevalent. The result is that the unprotected emigrants become infected, and if they immediately embark they may not only reach the port of destination before the incubation period has passed, but may pass the quarantine in apparently perfect health. And, what is still more important, if such infected immigrants immediately on landing take passage on board the immigrant trains, as vast numbers do, they may reach the most distant settlements before the disease finally develops. It is quite plain that under these circumstances no amount of vigilance in merely searching for the sick can prevent the introduction and wide dessemination of small-pox in this country. And this conclusion has tenfold force when applied to the introduction of small-pox from the Dominion of Canada by means of immigrants.

*Fifth.*—It is a noticeable fact that large numbers of immigrants are found, on inspection, to be unvaccinated. This might be inferred from the fact that such a large proportion of the total number are children. Of the 457,257 immigrants arriving in the year 1880, 87,154, or about one-fifth, were under 15 years of age. It is found also that an intense predjudice exists against vaccination on the part of several nationalities. In several instances compulsory measures have been resorted to at the port of New York to compel the vaccination of unprotected persons who have been exposed to the infection. These immigrants have been known to wash their vaccination wounds immediately after the operation, and in some instances they have been detected having another person, as the mother of a child, suck the wound to remove the virus.

The measures at present adopted and relied on to prevent the introduction and spread of small-pox in the United States by immigrants are evidently inadequate to meet existing conditions. Our health officials are pursuing the methods of prevention in vogue before the era of steam ocean and land travel. Thus far at the port of arrival the health officer takes cognizance only of vessels having well-marked small-pox cases on board, either in transit or on arrival. In this case the vessel is subjected to cleansing and disinfection, and the passengers are vaccinated and allowed to depart, no further care being taken to insure successful disinfection of baggage, nor of the vaccination of the unprotected. The immigrant trains proceed to their destination, scattering their occupants along the way without further sanitary care or inspection. Wherever the immigrant stops he seeks the low lodging-house, and there the disease that he has carried in his system from the port of embarkation may first develop itself and establish a focus or infection which may and often has of late involved a whole town in disaster.

The first knowledge that the local health authorities have of the arrival of the pestilence is its apparently sudden outbreak. It is evident not only from our past experience, but from the nature of the case as developed in the preceding recital of facts, that the methods we are now pursuing will not prevent the introduction of small-pox into the United States, nor control in any proper sense its spread. There is every indication that the amount of immigration will not be diminished, and that small-pox will become more and more prevalent abroad. To meet this emergency it is the duty of this conference to determine upon a practicable plan of concentrated operations adequate to accomplish the purpose in question. In this view the following scheme is proposed for consideration:

It is evident we can no longer rely simply on quarantine rule, which secures vaccination only of those on board vessels having had small-pox cases during the voyage. The future rule must be that all immigrants shall give satisfactory evidence of being protected against small-pox before being allowed to land. There are two methods of accomplishing this object:

(1.) The restrictions of quarantine may be so applied as to make obligatory upon steamship owners to cause a medical inspection of all emigrants when they embark, and vaccination of all persons found unprotected. If this plan were carried out in good faith scarcely an immigrant could reach our ports who would develop small-pox. He could only carry the infection in his baggage. But if proper sanitary care of the baggage was required, that also could be relieved of infection on the voyage. It is doubtful, however, if these measures could be fully carried into effect without Congressional legislation, and it should be a part of the action of this conference to secure the insertion of such provisions into the bill pending before Congress regulating immigration as will accomplish the results mentioned.

(2.) The second method is the establishment of medical inspections of all steerage passengers at the ports of arrival in the United States with power to vaccinate all persons found unprotected. This method can be put into operation at once by adding to the rules regulating quarantine one requiring the inspection and vaccination of all immigrants found unprotected. In localities or ports where local boards make the rules governing quarantine, this rule could be at once adopted. Where State legislation is necessary to make the rule, which cannot be attained, the National Board of Health could make the rule and render it effective, or the National Board of Health could make the rule for the several great immigrant ports, and the local officers could enforce it. From the following table it appears that the number of immigrant ports is very few and can be readily brought under a system of efficient inspection.

| Customs districts at which arrived. | Total immigrants for year ending June 30, 1880. | | |
|---|---|---|---|
| | Males. | Females. | Total. |
| Alaska | 95 | 12 | 107 |
| Baltimore | 10,071 | 7,823 | 17,894 |
| Boston | 18,797 | 15,265 | 34,062 |
| Buffalo | 484 | 533 | 1,017 |
| Charleston | 3 | 1 | 4 |
| Chicago | 250 | 138 | 388 |
| Cuyahoga, Ohio | 38 | 16 | 54 |
| Detroit | 2,565 | 2,356 | 4,921 |
| Duluth | 698 | 169 | 867 |
| Galveston | 7 | ........ | 7 |
| Gloucester, Mass | 306 | 16 | 322 |
| Port Huron | 60,610 | 33,765 | 94,375 |
| Key West | 645 | 351 | 996 |
| Marblehead, Mass | 3 | 5 | 8 |
| Michigan | 168 | 53 | 221 |
| Milwaukee | 11 | 16 | 27 |
| Minnesota | 1,163 | 562 | 1,725 |
| New Bedford, Mass | 172 | 102 | 274 |
| New Haven | 6 | 3 | 9 |
| New Orleans | 1,744 | 919 | 2,663 |
| New York | 165,303 | 98,423 | 263,726 |
| Oregon | 691 | ........ | 691 |
| Oswego | 65 | 33 | 98 |
| Passamaquoddy | 1,974 | 912 | 2,886 |
| Pearl River, Mississippi | 1 | ........ | 1 |
| Philadelphia, Pennsylvania | 13,794 | 7,933 | 21,727 |
| Portland and Falmouth, Maine | 31 | 22 | 53 |
| Providence | 4 | ........ | 4 |
| San Francisco | 6,752 | 401 | 7,153 |
| Saint Mark's, Florida | 15 | 5 | 20 |
| Superior, Michigan | 1,157 | 300 | 1,457 |
| Total | 287,623 | 169,634 | 457,257 |

Through six ports it appears that the class of immigrants requiring inspection pass into the United States, viz: New York, Boston, Philadelphia, Baltimore, Detroit, Huron, and San Francisco. To these, perhaps, should be added Passamaquoddy Bay, Maine, and Minnesota. It is evident that a system of inspection and vaccination, such as here proposed, at the first arrival must be attended with as little detention as possible. Detention of three days for observation of the results of vaccination would result in the constant collection of from 20,000 to 30,000 persons in the quarantine of New York. Not only would such detention be unadvisable, owing to the hardship which it would create, but as a sanitary measure those vast hordes should be dispersed as rapidly as possible, and aided, rather than hindered, in their efforts to reach their future homes.

To meet the exigency which requires future inspection of those vaccinated, to verify the results, local inspection stations might be established at proper points along the great thoroughfares which the immigrant trains travel, where but a momentary detention would be required to reinspect the vaccinated, and when necessary to revaccinate. This inspection would be facilitated if a system of ticketing was followed, which might be arranged as follows: Let the port-inspector give to every person found to be protected a white card, having on it his name, age, nationality, date of inspection, and destination; to every person requiring vaccination let him give a red card, indorsed like the other, but giving date of vaccination. The immigrants would see that henceforward they must exhibit those cards when called upon. On inspection at a station those having white cards would be no further noticed, while those having red cards would be inspected as to vaccination. The number of inspection ports would not be large, as the routes of immigrant travel are well established. Buffalo, Pittsburgh, Wheeling, Cincinnati, Cleveland, Chicago, Saint Louis, Kansas City, and Saint Paul occur as centers through which most of this travel might be intercepted.

(3.) Within the State where the immigrants disperse for settlement there should be organized by the State board of health a system of surveillance which would keep them under observation until they reached their final destination. Such a system need not be complicated nor expensive, for the same tickets would be the means of preserving the identity of the individual. State boards of health have also an important duty to perform in securing vaccination. Through their official position they can exert a powerful influence upon the people by advice, and can organize many methods of bringing every community to feel a due sense of its obligation to adopt this measure of prevention.

(4.) Finally, the local health authorities could maintain, as far as necessary, a certain watchfulness over the immigrant family, in order to discover the first evidence of suspicious sickness.

But a more important duty rests upon the local boards, viz, persistent efforts to secure vaccination of every unprotected person within their jurisdiction. At this time, when there is great popular alarm in regard to small-pox, local boards should use their utmost efforts to make vaccination and revaccination (the only real safeguard against small-pox) universal. Vaccination should not only be offered but urged persistently upon those who neglect it, and restrictive measures, as expulsion from the public schools, should be enforced against those who refuse.

### THE RESOLUTIONS.

*Resolved*, 1. That small-pox is very prevalent in European ports at which emigrants embark for the United States, and, owing to the customary delay of the emigrants at these ports, unprotected persons are liable to, and frequently do, become infected with that disease.

2. That vast numbers of emigrants are unprotected against small-pox infection, and hence contract the disease just before embarking for the voyage.

3. That ocean transit is now so rapid that a person becoming infected with the small-pox poison may, and often does, reach the ports of the United States, and, even by rapid railroad travel, may locate in Western towns before the disease becomes apparent in the individual.

4. That outbreaks of small-pox in many parts of the United States and the liability to a wide and constant dissemination of the contagious and infectious material of that disease by means of the immense number of unprotected immigrants who daily land at our ports and immediately proceed to inland districts by railroad, demands the most energetic measures of health authorities to control the spread of this pestilence, and to exterminate it wherever it makes its appearance in any community.

5. That to accomplish this desirable object there should be concert of action among the several sanitary organizations of the country, viz, national, State, and municipal, and each in its own sphere should use its utmost power to stamp out this disease.

6. That, with a view to give practical effect to the objects of this conference, we recommend—

(A.) That Congress incorporate into the law regulating immigration a provision requiring protection from small-pox by successful vaccination of all immigrants.

(B.) That the National Board of Health is requested to consider (in accordance with an act to prevent the introduction of contagious or infectious diseases into the United States, approved June 2, 1879) the propriety of making, promulgating, and enforcing rules requiring the inspection at the port of departure of immigrants into this country, and the vaccination or revaccination of every immigrant who, upon such inspection, is found unprotected from small-pox. Or, failing in any case or for any cause to secure such vaccination or revaccination, to prevent such unprotected persons as may have come from or through any infected district from taking passage on any ship destined for this country during the period of the incubation of the disease until such time shall have elapsed as shall make it certain that they are not carrying the germs of small-pox in their own persons.

(C.) That notification be sent to the various steamship companies bringing immigrants to the United States, that unless satisfactory evidence of recent vaccination be furnished (by certificate or otherwise) in the case of each immigrant arriving at any port of the United States, such vessels should be quarantined for a sufficient time to insure the development of all undeveloped cases of small-pox, as well as for the discovery, if possible, of concealed existing cases which have developed during the voyage.

(D.) That local health authorities should as far as practicable cause a thorough inspection of immigrants at all distributing points, and the detention at such points of all suffering from small-pox, and also the vaccination by the local authorities, if needed, of all immigrants who arrive at their destination.

(E.) That to meet present emergencies the National Board of Health, by virtue of its power to prevent the introduction of contagious and infectious diseases into the United States and their spread from one State into another, take such measures as will secure the inspection of every immigrant before landing at the ports of the United States, and of the vaccination of all persons not protected.

(F.) That a committee consisting of one from each State and local board represented be appointed, whose duty it shall be to take such measures as may be found necessary to accomplish the objects of these resolutions.

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## *ACTION OF STATE BOARDS OF HEALTH IN REGARD TO THE INTRODUCTION AND SPREAD OF SMALL-POX IN THE UNITED STATES.*

### STATE BOARD OF HEALTH OF NEW YORK.

The following preambles and resolutions were adopted by the New York State board of Health June 22:

"Whereas it is believed that small-pox is at the present time prevailing as an epidemic in some of the ports of the British Islands and of continental Europe; and

"Whereas the emigration from those countries to the United States, principally through the port of New York, is at the present time unprecedented in its extent, and recognizing the fact that the incubative period of the disease is greater than the average passage of steamships from such ports to ports in the United States, thus affording an opportunity for emigrants infected at the port of departure to pass our quarantine and reach interior communities before the development of the disease:

"*Resolved*, That this board request the National Board of Health, as a necessary measure of inter-State quarantine, to appoint an inspector of emigrants at Buffalo and Suspension Bridge, whose duty it shall be to examine all emigrants passing through or stopping off at the places mentioned."

And this board further respectfully recommend that the National Board of Health establish such inspections at Chicago, Pittsburgh, Saint Louis, and Omaha during the epidemic prevalence of small-pox at the ports from which emigrants embark.

### STATE BOARD OF HEALTH OF ILLINOIS.

At a meeting of the Illinois State board of health, held June 30, the following resolutions were unanimously adopted, and transmitted for publication by Dr. John H. Rauch, secretary:

"*Resolved*, That the Illinois State board of health cordially approves the action of the sanitary conference held in Chicago on the 29th and 30th of June, instant, for the prevention of the introduction of small-pox into this country by immigration and its spread from one State to another, and will co-operate, to the full extent of its power and means, in the proposed effort to unite all health authorities in a systematic plan of operations to prevent the extension of this disease and secure general vaccination.

"*Resolved*, That in view of the occurrence of small-pox in this State in epidemic form, through the dissemination of the contagion by emigrants arriving at the ports of the United States, the National Board of Health be, and is hereby, respectfully requested to secure the vaccination of all unprotected immigrants before they are allowed to leave the ports of arrival in this country.

"*Resolved*, That in accordance with the above the State board of health respectfully and earnestly call upon all health officers and local boards of health in this State to secure a careful inspection of all immigrants entering the State, and a prompt vaccination or revaccination of all persons not thus protected against small-pox."

### STATE BOARD OF HEALTH OF MICHIGAN.

The state board of health of Michigan adopted the following preambles and resolutions July 12, and transmitted by Dr. Henry B. Baker, secretary:

"Whereas many more immigrants enter the United States by the port at the city of Port Huron, Mich., than by any other port in this country, New York only excepted, the numbers at Port Huron being about 100,000 annually, and no quarantine or inspection is maintained there by any health authority; and

"Whereas the country is suffering from contagious diseases, and especially small-pox, introduced in many cases by immigrants, their baggage, wearing apparel, &c., and it is a matter of national importance that the introduction of these diseases be checked as soon as possible; and

"Whereas, while the laws of Michigan provide for quarantine and disinfection by the local health authorities at expense of persons quarantined, there is no State or municipal fund available for inspection, vaccination, and disinfection of persons and things in transit and without detention: Therefore,

"*Resolved*, That in accordance with section 3 of an act to prevent the introduction of infectious and contagious diseases into the United States, approved June 2, 1879, the National Board of Health is respectfully requested to make and submit for approval by the President of the United States 'such additional rules and regulations as are necessary,' and either authorize this State board to execute such rules and regulations, at the expense of the National Board of Health, or appoint a health officer of the port, or a sanitary inspector of the port, and such assistants as may be necessary, at the city of Port Huron, Mich., whose duties shall be to examine, while in transit and without detention, all immigrants arriving at that port; to detain or effectually *isolate in transit* all persons suffering from small-pox, diphtheria, scarlet fever, typhus fever, cholera, yellow fever, or any other disease dangerous to the public health; to disinfect all infected baggage, wearing apparel, cars, vessels, ferry boats, &c., and to vaccinate, with pure and fresh bovine vaccine virus, all immigrants unprotected from small-pox, and recently exposed to that disease, or coming from or through infected places; to report to the National Board of Health respecting all vaccinations and re-vaccinations made by them; to co-operate with State and other boards of health, and to promptly communicate to such boards of health information relative to the entry or proposed entry within their jurisdiction of immigrants, and the facts respecting their liability or non-liability to introduce any disease dangerous to the public health.

"*Resolved*, That the National Board of Health is respectfully requested to consider the propriety of taking action, similar to that requested relative to Port Huron, respecting other ports to the eastward of this State where such action as is herein suggested, has not been inaugurated, and from whence immigrants come and pass into and through this State, and may thus endanger citizens of Michigan more than do immigrants by way of Port Huron, many of whom pass directly on to cities and States farther west."

"Whereas immigrants exposed to small-pox in foreign countries may contract the disease, cross the ocean, and reach places far inland in this country before the disease manifests itself in their persons; and

"Whereas vaccination on arrival in this country is usually too late to prevent the occurrence of the disease in susceptible persons exposed to small-pox on the other side of the Atlantic Ocean: Therefore,

"*Resolved*, That the National Board of Health is hereby earnestly requested to consider (in accordance with an act to prevent the introduction of contagious or infectious diseases into the United States, approved June 2, 1879) the propriety of making, promulgating, and enforcing rules requiring the inspection at the port of departure of immigrants into this country, and the vaccination or revaccination of every immigrant who, upon such inspection, is found unprotected from small-pox. Or, failing in any case for any cause to secure such vaccination or revaccination, to prevent such unprotected person as may have come from or through any infected district from taking passage on any ship destined for this country or, at least, from landing in this country during the period of incubation of the disease and until such time shall have elapsed as shall make it certain that they are not carrying the germs of small-pox in their own persons.

"*Resolved*, That the Michigan State board of health cordially approves the action of the sanitary conference held in Chicago June 29 and 30, for the prevention of the further introduction of small-pox into this country by immigrants, and its spread from one State into another, and that in the proposed effort to unite all health authorities in an organized plan of concerted action to prevent the extension of small-pox and to secure future immunity from small-pox by means of general vaccination, this board will co-operate to the full extent of its powers.

"*Resolved*, That the attention of every local board of health in Michigan is respectfully asked to the details of the plan for immediate action recommended by the late sanitary conference at Chicago, which, in connection with the preceding preambles and resolutions, is further indicated as follows:

"'That to meet present emergencies the National Board of Health, by virtue of its power to prevent the introduction of contagious and infectious diseases into the United States and their spread from one State into another, be requested to take such measures as will secure the inspection of every immigrant before landing at the ports of the United States, and of the vaccination of all persons not protected.

"'That local health authorities should, as far as practicable, cause a thorough inspection of immigrants at all distributing points, and the detention at such points of all suffering from small-pox, and also the vaccination by the local authorities, if needed, of all immigrants who arrive at their destination.

"'Finally, the local health authorities could maintain, as far as necessary, a certain watchfulness over the immigrant family in order to discover the first evidence of suspicious sickness.

"'But a more important duty rests upon the local boards, viz, persistent efforts to secure vaccination of unprotected persons within their jurisdiction. At this time, when there is great popular alarm in regard to small-pox, local boards should use their utmost efforts to make vaccination and revaccination (the only real safeguard against small-pox) universal. Vaccination should not only be offered, but urged persistently upon those who neglect it, and restrictive measures, as expulsion from the public schools, should be enforced against those who refuse.'

"*Resolved*, That, in accordance with the foregoing, the State board of health respectfully and earnestly calls upon all health officers and local boards of health in Michigan to secure a careful inspection of all immigrants entering and remaining within their jurisdiction, and a prompt vaccination or revaccination (with pure and fresh bovine vaccine virus) of all persons not protected against small-pox; these precautions being especially necessary respecting immigrants, because of their having come in contact with people and baggage from nearly all parts of the world, and therefore very much more liable to have picked up the contagia of diseases than are our citizens at their homes."

### STATE BOARD OF HEALTH OF IOWA

The Iowa State board of health adopted the following resolutions, which were transmitted by the secretary, Dr. R. J. Farquharson:

"The Iowa State board of health indorses the action of the sanitary conference, held in Chicago June 29 and 30, for the prevention of the introduction of small-pox by immigration and its spread from one State to another, and will unite and co-operate, to the full extent of its power and means, in a systematic plan of operation to prevent the extension of this disease and secure general vaccination.

"In view of the fact of the frequent introduction of small-pox into the interior of Iowa from immigrants, the Iowa State board of health would respectfully request the National Board of Health to secure the vaccination of all unprotected immigrants before they leave the ports of arrival in this country.

"The Iowa State board of health therefore earnestly requests all health officers and local boards of health to secure a careful inspection of all immigrants entering this State and a prompt vaccination and revaccination of all persons not sufficiently protected against small-pox."

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## *RULES AND REGULATIONS FOR SECURING THE BEST SANITARY CONDITION OF VESSELS, INCLUDING THEIR CARGOES, PASSENGERS, AND CREWS, COMING TO THE UNITED STATES FROM ANY FOREIGN PORT WHERE ANY CONTAGIOUS OR INFECTIOUS DISEASE EXISTS.*

[Prepared by the NATIONAL BOARD OF HEALTH, in accordance with the provisions of an act approved June 2, 1879, entitled "An act to prevent the introduction of infectious or contagious diseases into the United States."]

### EXPLANATIONS.

1. The object of the following rules and regulations is to prevent the introduction into the United States of "contagious or infectious diseases."

2. The following diseases are recognized as "contagious or infectious diseases," for the purposes of these rules and regulations, viz: Asiatic cholera, yellow fever, plague, small-pox, typhus fever, and relapsing fever.

3. An "infected" port or place, in the sense of these rules, is a port or place at which either Asiatic cholera, yellow fever, plague, small-pox, relapsing fever, or typhus fever exists.

4. To secure the "best sanitary condition" of a vessel, the following points shall be observed by the owners, agents, or master of such vessel:

A. Exclusion from the vessel, as far as possible, of persons or things known or suspected to be infected.

B. Cleanliness, dryness, and ventilation of the vessel, both preliminary to loading and during the voyage.

C. Disinfection—that is, the destruction or removal of the causes of disease—which includes measures of cleanliness, ventilation, fumigation, &c.

D. The crew shall not be allowed liberty on shore after nightfall in suspected localities. They shall not be allowed to sleep on deck except under awnings. The forecastle shall be well ventilated and kept dry. Both in port and at sea the bilge shall be pumped out each morning and evening, or more frequently, if necessary. The utmost cleanliness shall be observed at sea as well as in port. Each seaman shall have two suits of underclothing. The clothing and bedding shall be aired every clear day. In tropical climates the men shall be required to wash their persons and change their underclothing every evening after work while in port, and each working suit shall be washed, dried, and aired after a day's use. These regulations as to clothing, airing of bedding, and ventilation, shall, as far as possible, be observed at sea as well as in port.

### RULES AND REGULATIONS.

1. All merchant ships and vessels sailing from a foreign port where contagious or infectious disease exists, for any port of the United States, must obtain from the consul, vice-consul, or other consular officer of the United States, at the port of departure, or from the medical officer—where such officer has been detailed by the President for that purpose—a bill of health in duplicate, which shall set forth the sanitary history of said vessel, and that it has in all respects complied with these rules and regulations.

2. No vessel shall have more than one bill of health; but if she touches at other ports on the passage, that fact and the condition of those ports as to the existence of contagious or infectious disease shall be indorsed upon the original bill of health by the consul, vice-consul, consular officer, or medical officer of the United States.

3. The bill of health shall be in the form appended:

### FORM A.

No. —. *Port of* ———.

### THE UNITED STATES OF AMERICA—NATIONAL BOARD OF HEALTH.

### *Bill of health.*

I, ——— ——— (the person charged to deliver the bill), at the port of ———, do hereby state that the vessel hereinafter named clears from this port under the following circumstances:

Name of vessel: ——.
Tonnage: ——.
Apartment for passengers, No.—.
Destination: ——.
Name of medical officer (if any): ——.
Total number of passengers: 1st cabin, ——; 2d cabin, ——; steerage, ——.

Nature (vessel of war, ship, schooner, &c.): ——.
Guns: ——.
Where last from: ——.
Name of captain: ——.
Total number of crew: ——.
Cargo: ——.

### *Vessel.*

1. Sanitary history of the vessel: ——.
2. Sanitary condition of vessel (before and after reception of cargo, with note of any decayed wood). Note disinfection of vessel: ——.
3. Sanitary condition of cargo: ——.
4. Sanitary condition of crew: ——.
5. Sanitary condition of passengers: ——.
6. Sanitary condition of clothing, food, water, air-space, and ventilation: ——.

*Port.*

1. Sanitary condition of port and adjacent country—
    *a.* Prevailing disease (if any):
    *b.* Number of cases of and deaths from yellow fever, Asiatic cholera, plague, small-pox, or typhus fever during the week preceding—

| Number of cases of— | Number of deaths from— |
|---|---|
| Yellow fever: ——. | Yellow fever: ——. |
| Asiatic cholera: ——. | Asiatic cholera: ——. |
| Plague: ——. | Plague: ——. |
| Small-pox: ——. | Small-pox: ——. |
| Typhus fever: ——. | Typhus fever: ——. |

    *c.* Population according to the last census: ——.
    *d.* Total deaths from all causes during the preceding month: ——
2. Any circumstances affecting the public health existing in the port of departure to be here stated: ——

I certify that I have personally inspected the said vessel, and that the above statements are correct.

—— ——.
[Signature of medical officer.]

I certify that the foregoing statements are made by —— ——, who has personally inspected said vessel; that I am satisfied that the said statements are correct; and I do further certify that the said vessel leaves this port, bound for ——, in ——.

In witness whereof I have hereunto set my hand and the seal of office, at the port of ——, this — day of ——, 188–, — o'clock.

[SEAL.]

—— ——.
[Signature.]

4. Each consul, vice-consul, consular officer, or medical officer of the United States in a foreign port shall keep himself thoroughly acquainted with the sanitary condition of the port and its vicinity, especially with regard to the existence of contagious or infectious diseases or epidemics, and shall, upon the request of the owner, agent, or master, make, or cause to be made, an inspection of every ship or vessel bound for any port in the United States, and give the bill of health required by these regulations. Vessels carrying a foreign flag shall be inspected, when practicable, in company with the consul or consular agent of the nation to which the vessel belongs.

5. The fee for such inspection shall be such as may be fixed by the Secretary of the Treasury.

6. The certifying authority at the port of departure shall certify whether vessels carrying passengers are provided with the means of carrying out the provisions of sections 4257 and 4263 of the Revised Statutes.

SEC. 4257. Every such vessel so employed in transporting passengers between the United States and Europe, and having space according to law for more than one hundred such passengers, shall have at least two ventilators to purify each apartment occupied by such passengers; one of which shall be inserted in the after part and the other in the forward part of the apartment, and one of them shall have an exhausting-cap to carry off the foul air, and the other a receiving-cap to carry down the fresh air. Such ventilators shall have a capacity proportioned to the size of the apartments to be purified; namely, if the apartment wil llawfully authorize the reception of two hundred such passengers, the capacity of each such ventilator shall be equal to a tube of twelve inches diameter in the clear, and in proportion for larger or smaller apartments. All such ventilators shall rise at least four feet six inches above the upper deck of any such vessel, and be of the most approved form and construction. If it appears from the report to be made and approved, as provided in section forty-two hundred and seventy-two, that such vessel is equally well ventilated by any other means, such other means of ventilation shall be deemed to be a compliance with the provisions of this section.

SEC. 4263. The master of any vessel employed in transporting passengers between the United States and Europe is authorized to maintain good discipline and such habits of cleanliness among passengers as will tend to the preservation and promotion of health; and to that end he shall cause such regulations as he may adopt for this purpose to be posted up, before sailing, on board such vessel, in a place accessible to such passengers, and shall keep the same so posted up during the voyage. Such master shall cause the apartments occupied by such passengers to be kept at all times in a clean, healthy state; and the owners of every such vessel so employed are required to construct the decks and all parts of the apartments so that they can be thoroughly cleansed; and also to provide a safe, convenient privy, or water-closet, for the exclusive use of every one hundred such passengers. The master shall also, when the weather is such that the passengers cannot be mustered on deck with their bedding, and at such other times as he may deem necessary, cause the deck occupied by such passengers to be cleansed with chloride of lime, or some other equally efficient disinfecting agent. And for each neglect or violation of any of the provisions of this section, the master and owner of any such vessel shall be severally liable to the United States in a penalty of fifty dollars, to be recovered in any circuit or district court within the jurisdiction of which such vessel may arrive or from which she is about to depart, or at any place where the owner or master may be found.

7. For the purpose of isolating the sick, especially those suffering from contagious or infectious diseases, every steamship or other passenger vessel shall have two compartments or spaces to be used as hospitals, one for men and the other for women. These hospitals shall, when practicable, be constructed on the main deck, or on the deck next below the uppermost deck of the vessel.

8. Every vessel before taking on cargo or passengers shall be clean and dry, and the certifying officer may, at his discretion, require that it shall be thoroughly disinfected if last from an *infected* port, or if the port of departure be itself *infected*. The examination of the vessel as to cleanliness shall be made before the cargo is taken on, and shall extend to all accessible parts, especial care being taken to note upon the bill of health the presence of decayed wood.

9. Earth and porous stone shall not be used for ballast if avoidable.

10. Merchandise or articles known to be infected shall not be received or taken on board.

11. In case the port is *infected*, the certifying authority may require that the officers, crew, and passengers shall be examined by a medical officer or physician selected for that purpose, and the result reported to him not more than twenty-four hours before certifying to the bill of health.

If small-pox exists at the port, the certifying authority shall require that the medical examination above provided shall extend to all passengers, as well as to the officers and crew, for the purpose of determining their protection against small-pox, and every person found unvaccinated, or not satisfactorily protected, shall be properly vaccinated before the vessel leaves the port, and a record of such vaccinations, including the name of each individual vaccinated, and the date of vaccination, shall be given to the master of the vessel, to be by him delivered to the quarantine authority at the port of arrival.

12. Bills of health can be considered valid only when delivered within twenty-four hours last preceding departure. If the departure is delayed beyond this period the bill must be *visé* by the authority delivering it, stating whatever changes have taken place in the sanitary condition of the port, vessel, officers, crew, or passengers.

13. When the port of departure or its vicinity is *infected*, that fact shall be noted in the bill of health, and when the sanitary or other local authority of the port declares the existence of such infection, the bill of health shall give the date of said declaration.

14. A port shall not be considered infected by reason of the existence of contagious or infectious disease confined within the limits of the quarantine station of such port.

15. Physicians attached to sea-going vessels shall be specially charged with the duty of watching their sanitary condition and the health of their officers, crew, and passengers. On arrival of the vessel they shall report to the health officer of the port the sanitary history of the voyage.

16. In case of the occurrence at sea of Asiatic cholera, yellow fever, plague, small-pox, relapsing fever, or typhus fever, the wearing apparel and bedding used by those affected with such disease shall be boiled for not less than two hours, or burnt or sunk.

17. Captains, owners, or agents of vessels shall, at the port of departure, be required to answer, under oath, to the consuls or sanitary officers all questions as to the sanitary condition of the vessel, &c.

18. Whenever any vessel shall leave an *infected* foreign port, or, having on board goods or passengers coming from any place or district infected with Asiatic cholera, yellow fever, or plague, shall leave any foreign port bound for any port in the United States, the consul, consular officer, or other representative of the United States at or near such port may, at his discretion, immediately give information thereof by telegraph to the National Board of Health, at Washington, D. C., reporting the name, date of departure, and port of destination of such vessel. The cost of such telegrams will be paid by the National Board of Health.

19. All merchant ships or vessels from any foreign port where any contagious or infectious disease exists, and bound for any port of the United States, must present to the health officers at the quarantine station of such port evidence that these rules and

regulations have been complied with in order that such vessel may enter such port, discharge its cargo, and land its passengers.

J. L. CABELL,
*President National Board of Health.*

THOMAS J. TURNER,
*Secretary National Board of Health.*

OFFICE OF THE PRESIDENT OF THE UNITED STATES,
*November* 14, 1881.

The foregoing rules and regulations are hereby approved.

CHESTER A. ARTHUR.

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## *ADDITIONAL RULES AND REGULATIONS NECESSARY TO PREVENT THE INTRODUCTION OF SMALL-POX INTO THE UNITED STATES FROM FOREIGN COUNTRIES.*

1. That all persons coming from or through any foreign port or place in which small-pox exists, who, after the 14th day of November, 1881, shall arrive at any port of entry within the United States, shall be subjected to examination as regards their protection from that disease by the proper health authorities of the State within which such port lies, or in case such authorities shall fail or refuse to enforce this rule, then by some officer or other proper person to be designated by the President of the United States.

2. That in case any person so arriving shall refuse to submit to such examination, or upon undergoing the same shall be found not sufficiently protected from small-pox, such person, and in case he or she be not *sui juris*, then also the person having him or her under charge, shall be detained in quarantine until he or she shall have been properly vaccinated, or shall have passed the period of incubation from date of last exposure.

J. L. CABELL,
*President National Board of Health.*

THOMAS J. TURNER,
*Secretary National Board of Health.*

OFFICE OF THE PRESIDENT OF THE UNITED STATES,
*November* 14, 1881.

The foregoing additional rules and regulations are hereby approved.

CHESTER A. ARTHUR.

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